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(This issue completes Volume VI. Title page and table of contents are stitched in the middle of this issue.)

Correlation of Microclimatic Factors with Species Distribution in Shenk's Woods, Howard County, Indiana

RAY C. FRIESNER and CHARLES M. EK (Pp. 87-101)

Survival of Hemlock Seedlings in a Relict Colony under Forest Conditions

RAY C. FRIESNER and JOHN E. POTZGER (Pp. 102-115)

The Vegetation of Round Island (Straits of Mackinac), Michigan

JOHN E. POTZGER (Pp. 116-122)

Pollen Frequency of Abies and Picea in Peat: A Correction on Some Published Records from Indiana Bogs and Lakes

JOHN E. POTZGER (Pp. 123-130)

Notes on Distribution and Bio-ecology of Characeae in Nebraska

WALTER KIENER (Pp. 131-148)

The Characeae of Nebraska

FAY KENOYER DAILY (Pp. 149-171)

Papers 9-12 are contributions No. 158-161 from the Botany laboratories of Butler University and papers 13 and 14 are joint contributions from the Nebraska Game, Forestation and Parks Commission, the University of Nebraska Conservation and Survey Division, and the botany laboratories of Butler University.

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VOLUME IV

1. Contrasts in certain physical factors in Fagus-Acer and Quercus-Carya communities in Brown and Bartholomew counties, Indiana, by Ray C. Friesner and J. E. Potzger. Pp. 1-12. September, 1937.
2. A quantitative study of the phytoplankton of the White river canal, Indianapolis, Indiana, by Charlene Coffing. Pp. 13-31. September, 1937.
3. Fossil pollen analysis of Fox Prairie bog, Hamilton county, Indiana, by Robert L. Prettyman. Pp. 33-42. November, 1937.
4. Pollen spectrum of Lake Cicott bog, Cass county, Indiana, by William M. Smith. Pp. 43-54. November, 1937.
5. Pollen study of Cranberry pond, near Emporia, Madison county, Indiana, by Jean Barnett. Pp. 55-64. November, 1937.
6. A quantitative study of the phytoplankton of Lake Michigan collected in the vicinity of Evanston, Illinois, by William Allen Daily. Pp. 65-83. December, 1938.
7. A comparison of market milk from ten Indianapolis companies by use of the direct microscopic method of analysis, by Ina Stanley. Pp. 85-92. December, 1938.
8. Forest succession in the southern limits of Early Wisconsin glaciation as indicated by a pollen spectrum from Bacon's swamp, Marion county, Indiana, by James H. Otto. Pp. 93-116. December, 1938.
9. A fossil pollen study of Kokomo bog, Howard county, Indiana, by John W. Howell. Pp. 117-127. December, 1938.
10. A pollen profile of Otterbein bog, Warren county, Indiana, by Ruth Rebekah Richards. Pp. 128-140. December, 1938.
11. Key to species and varieties of ferns and fern allies of northeastern North American, by Ray C. Friesner. Pp. 141-162. August, 1940.
12. A phytosciological study of the herbaceous plants in two types of forests in central Indiana, by J. E. Potzger and Ray C. Friesner. Pp. 163-180. August, 1940.
13. What is climax in central Indiana? A five-mile quadrat study, by J. E. Potzger and Ray C. Friesner. Pp. 181-195. August, 1940.
14. Some necessary nomenclatorial changes in the genus Solidago, by Ray C. Friesner. P. 196. August, 1940.
15. A study of asymmetrical growth from stump sections of *Quercus velutina*, by Ray C. Friesner. Pp. 197-206. August, 1940.

Continued on Inside Back Cover

CORRELATION OF MICROCLIMATIC FACTORS WITH SPECIES DISTRIBUTION IN SHENK'S WOODS, HOWARD COUNTY, INDIANA

By Ray C. Friesner and Charles M. Ek

In furtherance of the plan of the Botany Department of Butler University to place on record as rapidly as possible analyses of as many of the remnants of the forest primeval as can be studied before the woodsman's saw and ax make it too late, we here present an additional study in which certain microclimatic factors seemed to show a sharp, if not causal, correlation with the distribution of both woody and herbaceous species. Previous papers published as a part of this plan are those of Potzger and Friesner (1, 2, 3) and Potzger Friesner and Keller (4).

Shenk's woods is a tract of approximately 100 acres and is the first woods north of Sycamore Street road 6.5 miles east of Kokomo. At first sight the area very obviously supports two sharply differentiated forest types and this led to the additional study of causal relationships. The data upon which study was made were collected during the year 1941.

PHYSIOGRAPHY AND SOIL FEATURES

Shenk's woods occupies an area of almost flat and level land. Surface drainage is practically negligible though the site occupied by the Acer-Quercus-Fagus community is, at its extreme elevation, 1-2 feet higher than the lowest part of the area occupied by the Quercus-Ulmus community. Wildcat Creek has cut a valley 25-30 feet deeper than the level of this woods and paralleling it a mile to the south and so probably receives, via underground drainage, what drainage the area has.

The soil of the woods is a heavy clay loam underlain at considerable depth by glacial gravels. That occupied by the Acer-Quercus-Fagus community is somewhat less compact in texture with somewhat larger particles as evidenced by a lower moisture equivalent. A number of kettle-hole bogs as well as usable gravel deposits are within a few miles of the area.

METHODS

Sixty-five 100-square meter quadrats were used for securing the quantitative data; 25 being in area A, and 20 each in areas B and C. A stout cord divided by loops into four 10-meter sections, rolled on a reel, was used for outlining the limits of the quadrats. The loops were hung over sharpened wooden stakes forced into the ground and facilitated rapid demarkation of the areas. Quadrats were evenly spaced in rows which in turn were spaced so as to give a uniform distribution of the quadrats over each of the entire areas. During the procedure one person laid out the quadrats, another called the species and measured all stems 1-inch DBH. or above, a third worker recorded the stems as called, while a fourth wound up the cord, pulled stakes of completed quadrats and carried apparatus forward to the worker who laid out the quadrats. Such a team of 4 workers could readily complete as many as 100 quadrats in a day of work. All stems of young trees less than 1 inch DBH. but 1 meter high or over were also counted and recorded. From the data so compiled any size class could be used for whatever purpose it might later be needed in drawing conclusions. For example: basal areas computed from stems of tall tree species 3 inches DBH. and over would give a fair quantitative estimate of percentages in the crown cover; numbers of stems below 1 inch DBH. and 1 meter high or over were considered to present a reasonably accurate picture of reproduction.

In the center of each quadrat used for study of woody species in areas A and B there was also laid out, during the dormant season, a 1-meter quadrat which was later used for enumeration of the spring, summer and autumn herbaceous flora. The quadrats were delimited by heavy wire stakes at each of their four corners. When enumeration of the herbaceous flora was in progress a heavy cord slipped into loops at the top of each wire stake definitely laid off each quadrat from the surrounding area. Having thus been laid off during the dormant season, there was no chance for prejudice or selection in choosing more or less heavily populated sites for the quadrats. Such a procedure was followed in earlier work by Potzger and Friesner (5) in studies on the herbaceous species in different types of forest areas and found to be highly satisfactory.

Five atmometer stations were established in each of areas A and B and readings of evaporation loss were taken weekly from May 29 to September 20 inclusive. Atmometers were standardized at the beginning and the end of the season and all evaporation data were standardized to the mean coefficient of each atmometer which yielded them.

At the same time that atmometer data were being collected samples of soil were obtained within a radius of 10 meters of each atmometer and placed in air-tight containers for determination of soil moisture. Samples were taken in duplicate from surface (i.e., immediately under the duff layer), 6-inch and 12-inch depths. Percentage of moisture present in each sample, each week from May 1 through October 3, was determined by weighing the soils before and after dessication in a constant temperature oven at 103° C. The wilting coefficient of each soil was also obtained and from these two sets of figures the percentage of growth water in each sample for each week was obtained. Wilting coefficient was obtained by the formula $W.C. = \frac{ME}{1.84}$ where M.E. is the percentage of water remaining in soil previously saturated after centrifuging at 2440 revolutions per minute for 20 minutes.

RESULTS

WOODY FLORA

Results from quadrat studies of woody flora are tabulated and summarized in tables I and II. A study of these tables will show that area A and C may be considered Quercus-Ulmus areas and area B an Acer-Quercus-Fagus area. In area A, 48.61% of the crown cover (determined by the percentage of basal area of stems 3 inches and over DBH. among the tall tree species, i.e., excluding from consideration all under-story species) is made up of 4 of the more mesophytic species of Quercus, viz. *Q. bicolor, Q. borealis* var. *maxima, Q. macrocarpa* and *Q. muhlenbergii;* and 22.95% comprises 2 species of Ulmus, viz. *U. americana* and *U. fulva.* None of the Quercus species show a high frequency and all of them combined show an F. I. of only 48%. *Ulmus americana,* on the other hand, shows an F.I. of 84% and *U. fulva,* 40%. These differences are correlated with striking differences in the number of stems in smaller and larger size classes. Whereas in Quercus there are few stems below 16 inches DBH., in Ulmus 73% of the stems are below 3 inches DBH. Other species worthy of note in area A are *Acer saccharum,* 5.03% of the crown cover; *A. saccharinum,* 7.59;

Fraxinus americana, 6.03; *Platanus occidentalis,* 4.66. These data are presented in tabular form in table II.

Area C shows results quite similar to area A. The differences most worthy of note being a 4% increase in Quercus and the relative positions in crown cover between *Ulmus americana* and *U. fulva* being reversed. In addition, *Tilia americana* has made more than a fair showing and *Fagus grandifolia* shows a considerable increase.

In area B, on the other hand, a striking contrast is seen. Here *Acer saccharum* becomes the dominant species, occupying 58% of the crown cover while Quercus, still showing 16.97%, entirely lacks *Q. bicolor,* its most mesophytic form of area A. *Fagus grandifolia* occupies 9.88% of the crown cover in area B with other species as follows: *Ulmus fulva,* 7.21%; *Tilia americana,* 6.78% and *Fraxinus americana,* 6.78%.

HERBACEOUS FLORA

Study of the herbaceous flora in the two areas reveals some very striking differences (table III) which reflect the habitat differences and thus throw light upon the edaphic relations of the forest associations. It will be noted from the table that the early spring-flowering species are in low frequency or entirely absent in the Quercus-Ulmus area. Only 4 vernal species reach a frequency index above 20% and only one of these is very early in their time of flowering. They are *Arisaema atrorubens, Galium aparine, Osmorrhiza claytoni,* and *Viola eriocarpa.* The Acer-Quercus-Fagus area, on the other hand, contained 9 species with F.I. above 20% and the species present include the common early-flowering species of the region, e.g., *Claytonia virginica, Dentaria laciniata, Dicentra cucullaria, Erythronium americanum, Hydrophyllum appendiculatum, Ranunculus abortivus,* and *Viola eriocarpa.*

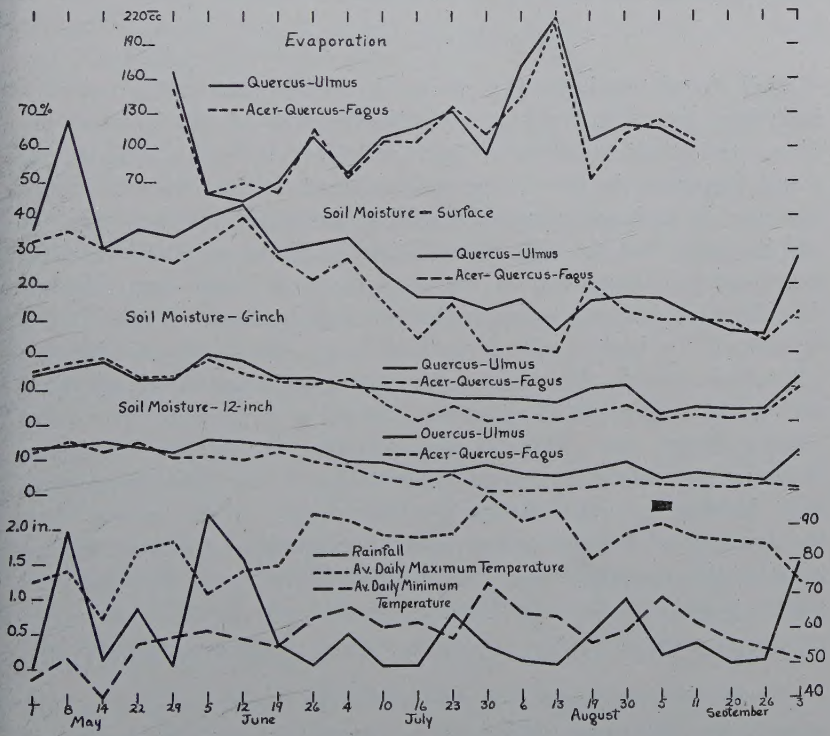
These differences in the vernal herbaceous flora are correlated with soil differences between the two areas. The soil of the Quercus-Ulumus area is much more compact, is composed of much more finely divided particles, and has a higher growth-water content in addition to a higher wilting coefficient than that of the Acer-Quercus-Fagus area. These differences would also seem to indicate a lower air content and a slower spring warming of the soil in the Quercus-Ulmus area.

The aestival species do not reveal any major differences of diagnostic value. The presence of *Impatiens biflora* (table II), in the Quercus-Ulmus area and its absence in the Acer-Quercus-Fagus area, together with the greater frequency of *Campanula americana* and *Osmorrhiza longistylis* in the former area, are the chief indicators among the aestival species.

The autumnal species are few and strikingly low in frequency but the high frequency of *Polyonum virginianum* in the Quercus-Ulmus area may have indicator value.

EVAPORATION DATA

Evaporation data collected from 5 atmometers stationed in each of the forest areas from May 22 to September 11 are shown in fig. 1. It will be seen that the curves (showing standardized results) very closely parallel each other emphasizing the correlation of the curves with weekly differences in meteorological data. If there are any



differences worthy of note between the data of the two areas they are the fact that when the evaporation rate is very high (e.g., weeks ending May 29 and August 6, 13) it is a little higher in the Quercus-Ulmus area than in the Acer-Quercus-Fagus area and that during 9 of the 16 weeks the rate of loss is higher in the former area while during 6 weeks it is higher in the latter area. In considering these differences it should be pointed out that the Quercus-Ulmus area occupies the northern part of the woods and the Acer-Quercus-Fagus area is in the southern portion. This, taken with the fact that the prevailing winds come from the southwest would, other things being equal, lead us to expect a generally higher loss in the Acer-Quercus-Fagus area. The slightly greater loss during the larger number of weeks in the Quercus-Ulmus area is associated with smaller frequency of understory species, the higher forest canopy and thus a more open area which permits better air circulation.

SOIL MOISTURE RELATIONS

Soils for determination of moisture conditions were taken weekly from May 1 to October 3 at 5 stations in each of the forest areas. They were taken at surface, 6-inch and 12-inch depths. Figures 2, 3 and 4 present the percentage of growth water, i.e., the percentage of water in each soil above the wilting coefficient for that soil. It will be noted that the wilting coefficient is higher at all horizons in the Quercus-Ulmus than in the Acer-Quercus-Fagus areas though the difference becomes successively less with increased depth of soil. In spite of the higher wilting coefficient, the remaining available soil moisture is considerably higher at all horizons for nearly every week during the season in the Quercus-Ulmus area than in the Acer-Quercus-Fagus area. This is especially true during the driest part of the season when the available moisture is lowest and the evaporation is highest. Thus during the critical part of the season when the demands of the atmosphere upon the vegetation for moisture are greatest the available supply in the soil is higher in the Quercus-Ulmus area.

CORRELATION OF FLORISTIC AND EDAPHIC FACTORS

From the foregoing it is apparent that the Shenk woods area falls sharply into two parts which differ materially both floristically and edaphically. The Quercus-Ulmus portion of this woods contains a forest camopy in which 4 of the more mesophytic species of Quercus and 2 species of Ulmus occupy 71.56% of the crown cover and from which the early spring herbaceous species are conspicuously absent. The soil is more compact with more finely divided particles and has a higher wilting coefficient, a higher total moisture content and a higher available moisture with a correspondingly lower air content. The few vernal-flowering herbaceous species present are those which flower later in the season, correlated with a slower spring warming of the soil, and whose subterranean organs can tolerate a less aerated soil.

The second portion of this woods contains a forest canopy in which *Acer saccharum* occupies 58% with Quercus and *Fagus grandifolia* occupying an additional 26.85% of the crown cover and in which the common early spring flowering species of this region are present. The soil is less compact with less finely divided particles, a lower wilting coefficient, a lower total moisture and lower available moisture content with a correspondingly higher aeration and more rapid warming rate in the early spring.

The data at hand do not clearly indicate whether the critical and determining edaphic factor differentiating the site for the Quercus-Ulmus area from that for the Acer-Quercus-Fagus area is soil moisture or soil air content. It is probable, since both areas contain nearly the same species of Quercus, though in considerably different percentages of crown cover, that the differentiation results from (1) the fact that Quercus and Ulmus occupy sites which *Acer saccharum* cannot tolerate (areas A and C) and (2) *Acer saccharum* finds more suitable edaphic conditions in area B where Quercus is present also but kept to a lower percentage by competition. This is to say, Quercus-Ulmus form a slightly more hydrophytic pre-climax and occupy sites which are not quite suitable for the climax species, *Acer saccharum* and *Fagus grandifolia.* There is a strong tendency as one studies this forest to conclude that soil aeration (the inverse of soil moisture and soil compactness) is the critical edaphic factor which limits the location of the Acer-Fagus association and, of course, indirectly through competition, also delimits the Quercus-Ulmus community.

CONCLUSIONS

1. The Shenk woods are is sharply differentiated into two types of forest communities, viz. Quercus-Ulmus and Acer-Quercus-Fagus.
2. The Quercus-Ulmus community occurs on soils which are

more compact, comprising more finely divided particles; with a higher wilting coefficient, higher growth water content and lower air content.

3. The Acer-Quercus-Fagus community occurs on soils which are less compact, with less finely divided particles; with a lower wilting coefficient, lower water content and higher air content.

4. Soil aeration is probably the critical factor limiting Acer and Fagus: Quercus and Ulmus occurring on sites with a lower air content than the former can tolerate and on sites with the former but in strong competition with them.

5. The vernal herbaceous flora shows a striking correlation with the woody species and with the edaphic conditions: the early flowering species being almost entirely absent in the Quercus-Ulmus communities where aeration is low, drainage poor and soil warming in the spring is late, but abundant in the Acer-Quercus-Fagus community.

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TABLE I

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

													Stems 3-in. or more	
Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Basal Area	% Crown Cover
Quercus alba	A	0										0	0	0
	B	0										0	0	0
	C	0	2		1				1	5	9	30	7140.07	30.4
Q. bicolor	A	0						5	4	1	10	20	5742.84	28.71
	B	1									0	5	0	0
	C	2					1		2	1	4	25	2446.53	10.3
Q. borealis var. maxima	A	2					5	1			8	24	2234.46	11.17
	B	9					1	1			2	35	663.66	4.65
	C	0									0	0	0	0
Q. macrocarpa	A						1			1	2	8	1332.04	6.66
	B									1	1	5	1320.26	9.42
	C								1	1	2	10	1237.79	5.3
Q. muhlenbergii	A						1	1			2	8	415.48	2.07
	B											0	0	0
	C											0	0	0
Q. shumardii	A											0	0	0
	B							1			1	5	415.48	2.90
	C							2	1		3	10	1611.64	6.9
Quercus—all species	A	2					7	6	6	3	22	48	9724.82	48.61
	B	10					1	2	0	1	4	50	2399.40	16.97
	C	2	2		1		1	2	5	7	18	65	12436.03	53.0
Ulmnus americana	A	21	62	18	3	4	3	1	2	1	95	84	3776.53	18.88
	B	89	1	1							2	30	7.07	.05
	C	2	12	5	0	1	0	1	1		20	65	1324.19	5.67

TABLE I (Continued)

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Stems 3-in. or more	
													Basal Area	% Crown Cover
U. fulva	A	20	8	2	1	5	1				17	40	914.54	4.07
	B	248	2	1		1	3				7	95	1026.51	7.21
	C	25	32	17	4	1	0	1	1	1	57	80	2688.74	11.5
Fraxinus americana	A	59	18	11	3		1		1		34	92	1207.39	6.03
	B	13				1					1	50	153.94	1.09
	C	19	5				1	1	1		8	65	1279.42	5.65
F. quadrangulata	A	0	1			1					2	4	113.10	.56
	B	0									0	0	0	0
	C	0				1					1	5	132.73	0.57
Acer saccharum	A	59	13	2	2	2	2				21	76	1007.33	5.03
	B	297	10	2	5	24	12	5			58	100	8113.22	58.00
	C	141	50	2	3	4		1			60	100	796.48	3.40
A. saccharinum	A	15	12	12	1		1	1	1		28	36	1518.98	7.59
	B	0	1								1	5	0	0
	C	2	0	1							1	15	7.07	.03
A. negundo	A	13	4								4	8	0	0
	B	1									0	5	0	0
	C	1	1	1							2	10	7.07	.03
Fagus grandifolia	A	0	1			1					2	8	176.72	.88
	B	7	15		1	3	1		1		21	25	1383.10	9.88
	C	1	1			3	1	1			6	30	1183.60	5.05
Celtis occidentalis	A	18	23	9	1		1				34	64	128.03	.64
	B	5	2								2	15	0	0
	C	10	14	2							16	55	26.71	.11

TABLE I (Continued)

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Stems 3-in. or more Basal Area	Stems 3-in. or more % Crown Cover
Carya cordiformis	A	11	3				1				4	36	254.47	1.27
	B	2									0	10	0	0
	C	7	1		1	1					3	35	255.26	1.09
C. ovata	A	6	1		4	1					6	36	288.23	1.44
	B	2									0	5	0	0
	C	1	2			1	1				4	25	490.88	2.10
Tilia americana	A	10	10	3			1				14	28	14.14	.07
	B	19	14	1				2			17	60	950.34	6.78
	C	6	11	3	4	1	5	1			25	40	2194.62	9.41
Liriodendron tulipifera	A	0	1	1	1						3	8	58.13	.29
	B	0									0	0	0	0
	C	0									0	0	0	0
Prunus serotina	A	0	1								1	4	0	0
	B	8									0	25	0	0
	C	4	7	2							9	40	25.14	.11
Juglans nigra	A	0									0	0	0	0
	B	1									0	5	0	0
	C	0									0	0	0	0
J. cinerea	A	1									0	4	0	0
	B	0									0	0	0	0
	C	0									0	0	0	0
Gymnocladus dioica	A	1									0	4	0	0
	B	0									0	0	0	0
	C	0	1								1	5	490.88	2.10

TABLE I (Continued)

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

													Stems 3-in. or more	
Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Basal Area	% Crown Cover
Platanus occidentalis	A	0					1		1		2	8	933.84	4.66
	B	0									0	0	0	0
	C	0							1		1	5	706.86	3.03
Aesculus glabra	A	4			1	1					2	16		
	B	10	1			1					2	50		
	C	2	1	1	8						10	50	383.87	
Morus rubra	A	0									0	0		
	B	0									0	0		
	C	1									0	5	0	
Carpinus caroliniana	A	26	9	5							14	44		
	B	1									0	5		
	C	8	3								3	40	0	
Ostrya virginiana	A	2	1	2							3	8		
	B	4									0	15		
	C	12	21	1	2						24	60	73.82	
Asimina triloba	A	42									0	16		
	B	183	63								63	45		
	C	103	6	0	2						8	25	106.81	
Cornus florida	A	0									0	0		
	B	0									0	0		
	C	0	1								1	5		
Crataegus sp?	A	0		1	1						2	8		
	B	0									0	0		
	C	0									0	0		

TABLE I (Continued)

Woody flora in 25 quadrats of area A and 20 quadrats each in areas B and C

													Stems 3-in. or more	
Species	Area	Below 1 in.	1-2	3-5	6-10	11-15	16-20	21-25	26-30	Above 30 in.	Total 1 in.+	F. I.	Basal Area	% Crown Cover
Evonymus atropurpureus	A	3									0	4		
	B	2									0	5		
	C	1									0	5		
Viburnum prunifolium	A	0									0	0		
	B	0									0	0		
	C	27									0	15		
Lindera benzoin	A	196									0	60		
	B	19									0	40		
	C	21	2								2	45		
Cornus asperifolia	A	131	6								6	48		
	B	1									0	5		
	C	20	16								16	50		
Smilax hispida	A	2										8		
	B	0										0		
	C	0										0		
Sambucus canadensis	A	1										4		
	B	0										0		
	C	0										0		
Vitis sp?	A	11										8		
	B	0										0		
	C	0										0		

Totals—A—20,116.25
B—14,033.58
C—23,338.82

TABLE II

Percentage of crown cover (based on basal areas of stems 3 inches or over DBH.) occupied by each of the important species of tall trees in each of the 3 areas.

Species of tall trees	Area A	Area B	Area C
Quercus spp.	48.61	16.97	53.00
Acer saccharum	5.03	58.00	3.40
Acer saccharinum	7.59	0	.03
Ulmus spp.	22.95	7.26	17.17
Fraxinus americana	6.03	1.09	5.65
Fagus grandifolia	0.88	9.88	5.05
Tilia americana	0.07	6.78	9.41
Plantanus occidentalis	4.66	0	3.03

TABLE III

Herbaceous species. Showing frequency index in Quercus-Ulmus and Acer-Quercus-Fagus areas.

Species	A. Quercus-Ulmus	B. Acer-Quercus-Fagus
Vernal Species		
Arisaema atrorubens	80	20
Claytonia virginica	16	50
Dentaria laciniata	0	40
Dicentra cucullaria	8	70
Erythronium americanum	0	50
Evonymus obovatus	16	0
Galium aparine	100	30
Geum vernum	16	20
Hydrophyllum appendiculatum	20	100
Osmorrhiza claytoni	60	40
Phlox divaricata	8	0
Ranunculus abortivus	8	30
Trillium recurvatum	0	20
Viola eriocarpa	48	100
Aestival Species		
Agastache nepetoides	0	20
Amphicarpa bracteata	20	20
Blephilia hirsuta	0	20
Campanula americana	60	20
Cryptotaenia canadensis	20	40
Cystopteris fragilis var. protrusa	0	20
Galium circaezans	0	20
G. triflorum	40	40
Geum canadense	100	80

TABLE III (Continued)

Herbaceous species. Showing frequency index in Quercus-Ulmus and Acer-Quercus-Fagus areas.

Species	A. Quercus-Ulmus	B. Acer-Quercus-Fagus
Hackelia virginiana	0	40
Impatiens biflora	40	0
Laportea canadensis	40	60
Monarda clinopodia	8	0
Osmorrhiza longistylis	60	20
Oxalis stricta	0	40
Parietaria pennsylvanica	0	80
Phryma leptostachya	60	80
Phytolaca americana	0	40
Pilea pumila	0	80
Prunella vulgaris var. lanceolata	0	20
Sanicula canadensis	60	40
Scutellaria lateriflora	0	20
Atumnal Species		
Aster sp.	20	20
Bidens frondosa	0	20
B. vulgata	20	0
Collinsonia canadensis	0	20
Desmodium paniculatum	0	20
Erigeron canadense	0	20
Hedeoma pulegioides	0	40
Helianthus decapetalus	0	20
Polygonum punctatum	0	20
P. virginianum	80	20
Scrophularia marilandica	0	20
Solanum nigrum	0	20
Solidago altissima	0	20
Verbena urticaefolia	0	20

SURVIVAL OF HEMLOCK SEEDLINGS IN A RELICT COLONY UNDER FOREST CONDITIONS

By RAY C. FRIESNER AND J. E. POTZGER

In previous papers (4, 5) we have discussed the ecological significance of *Tsuga canadensis* in Indiana. We have shown that hemlock occupies island-like sites surrounded by Fagus-Acer communities, that in these isolated stands ecological factors are more rigorous than in surrounding communities and that there is no advance in either size or position of the hemlock colonies. Daubenmire (3) and Moore, et al. (15) have shown that though hemlock communities may occur on sites which have physical appearance similar to those of Fagus-Acer communities, yet the former are always a little more xerophytic than the latter. We have also shown (17) that Tsuga seedlings are absent on that portion of the forest floor which is covered with any appreciable depth of forest litter such as invariably occurs on fairly level sites under a deciduous hardwood canopy. They occur in our region only on steeper slopes where there is sufficient moss or other floor covering to give the seeds lodgment, and in more nearly level sites only when the forest litter is not too deep. Study of edaphic and other ecologic conditions shows that every site containing Tsuga seedlings has lower growth-water content, greater soil temperature fluctuations, and higher evaporation rates than obtain in sites only a short distance removed from the seedling sites. Soil acidity appears, likewise, to be greater in sites containing Tsuga seedlings than in sites short distances away but without seedlings (16) and we have concluded that this is also one of the vital edaphic factors in its reproduction in Indiana.

An essential to the establishment of any forest species is the survival of its seedlings. In some species the first year seems to be the most critical one for survival while in other species early survival seems less difficult than a few years later when seedlings have reached a "sapling" stage. Haig, Davis and Weidman (8) have shown that 50% of the seedlings of western conifers die the first year, but those which survive this critical period have a good chance of future survival. Losses during the first year were due to biotic factors, insolation and a lack of sufficient moisture (in decreasing importance as named). Williams (20) has pointed out that seedlings of both beech and sugar maple are periodically abundant but beech seedlings do not survive as well in the early stages as maple while the high mortality rate of maple saplings later appears to make up for this great difference. In our earlier study of the factors concerned in hemlock reproduction (17) we found that 88.32% of hemlock seedlings perished during their first year. Toumey and Neethling (18) have shown that surface temperatures due to insolation play a vital role in the survival of hemlock seedlings. Studies made by the Lake States Forest Experiment Station (9) show that soil-surface temperatures in openings on Norway and Jack pine plantations in Minnesota reach as high as 175 degrees F. with continuous temperature of 130 F. for periods as long as 8.5 hours.

Since the roots of hemlock seedlings are usually shallow in comparison to those of other tree species, available moisture in the top three inches of soil becomes a critical factor, especially in seasons of subnormal rainfall. In our earlier paper on hemlock reproduction (17) we found that during the summer of 1930 the soil water was below the wilting coefficient in the top three inches of soil in sites containing hemlock seedlings for the entire months of June, July, and August. Rainfall for this summer season was 47.36% of normal and the survival was 17.20% for hemlock seedlings of 1- and 2-year ages (the only age classes studied). Williams (20) has pointed out that even though hemlocks periodically bear abundant crops of seeds, and in years of favorable moisture conditions, a fair amount of germination occurs, yet hemlock reproduction is at a standstill in the Cleveland area. This is apparently due to the fact that a subsequent dry season practically wipes them out. The conclusion that hemlocks are being replaced by beech and maple is inescapable. This is in accord with the view that hemlock is a relict of the Lake Forest. Baldwin (1) has pointed out that hemlock seeds are very erratic in their percentage of germination.

Graham (6) pointed out that while there was considerable hemlock establishment in the first decade following logging, there has been little since. During years when moisture on the forest floor is abundant, seedlings become numerous; but few seedlings become established, establishment being dependent upon the distribution of precipitation for the next few years.

It would thus appear that in areas where hemlock is a component of the climax, and not merely a relict, reproduction is dependent primarily upon a combination of three factors, viz. a good seed year followed by a good germinating year and these in turn followed by several years of favorable moisture conditions.

Maissurow (12) has shown that hemlock does not reproduce on the forest floor in northern Wisconsin but its reproduction often does occur on burned-over sites and all cases of high reproduction were traceable to surface fires. The conclusion was reached that even-aged stands of hemlock are unquestionably of fire origin or due to destruction of nature stands by fire, sleet, or logging.

METHODS

In April 1930, numbered linen tags were attached to wire stakes and placed beside several hundred seedlings of *Tsuga canadensis* growing on steep wooded slopes of Bean Blossom creek about 0.5 mi. southeast of Trevlac, in Brown county, Indiana. During the first summer many of the stakes were pulled and destroyed by passersby so that when observations were made in October of that year only 134 numbered trees remained undisturbed. During the first three October and April readings after the beginning of the project, new seedlings were tagged in less frequented sites of the same general area. During the second year, all linen tags were replaced with numbered metal tags. In October and April of each year for 10 years, observations were made on the number of seedlings surviving and at the end of this period all surviving seedlings were measured both as to diameter and height. The diameter measurements were taken at 5 cm. from the soil line. Sections were also taken from seedlings and from branches of nearby older trees for microscopic measurement of growth rings.

During the entire project a total of 1213 seedling were under observation. Of these, 450 came into the project either as first-year seedlings or as seedlings resulting from 1931 germination, 608 came in either as second-year seedlings or as seedlings resulting from 1930 germination, and 155 came in either as third-year seedlings or as seedlings resulting from 1929 germination.

During the season of 1930, soil moisture, soil temperature and evaporation data were taken weekly from 6 different sites containing hemlock seedlings. These data have been published in an earlier paper (17) and will be used here only as they have any bearing on the present problem, and to the extent that they were not used in the former paper.

Rainfall data were taken from the reports of the Hickory Hill station of the U. S. Weather Bureau, except for the winter of 1939-40 and the summer of 1940. The Hickory Hill station was about 3 miles from the area under observation. The data for January-March 1940 were taken from the Columbus station, about 25 miles east; and those for the summer of that year were taken from the Kelly Hill station, about 5 miles east of the seedlings.

SURVIVAL AND AGE

Data on survival are presented in table I. It will be noted that during the first summer season only 17.2% of the seedlings survived. Unfortunately, this happened to be the most severe season during the entire period of observation, only 47.36% of the normal-expected rainfall being recorded. Nearly twice the percentage of second-year seedlings survived as in the case of first-year seedlings. During the summers of 1930 and 1931, and the winter of 1930-31, the seedlings are listed in the table as 1st-year, 2nd-year and 3rd-year, but subsequent to the summer of 1931, they are listed in columns according to the season of their germination so that during the summer of 1932 the seedlings which were 1st-year seedlings of 1931 were now 2nd-year, while the following year they were 3rd-year and thus increased in succeeding years. Throughout the table, the data of the column (table I) headed "2nd-year" are from seedlings one year older than those of the column headed "1st-year"; and those of column headed "3rd-year" are in turn one year older than those of the "2nd-year" column.

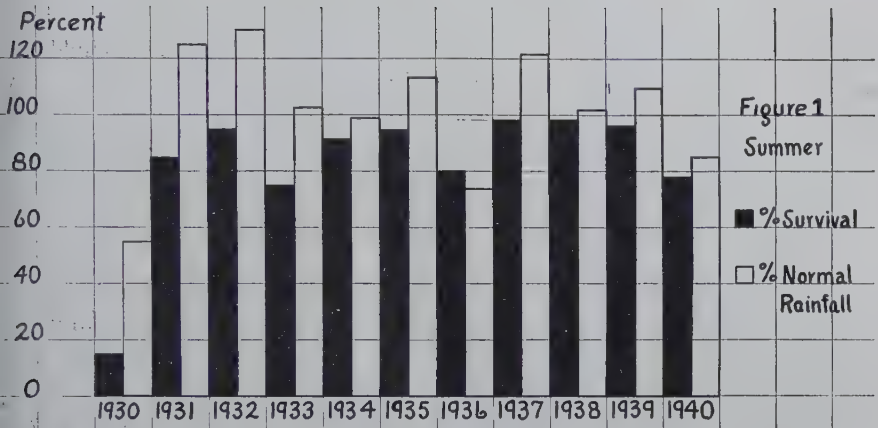
In comparing the survival data of these columns it will be noted that in nearly every instance the percentage of survival is lower in younger seedlings than in seedlings one year older when the data for the same season are compared. Exceptions are found in the summers of 1938 and 1939 when seedlings of the first column (now 7 and 8 years old) survived a little better than those of the second column (now 8 and 9 years old). During these summers the rainfall was above normal, the survival was high in all cases, and the number of seedlings concerned was so small that no particular significance can be attached to the slight difference in survivals. Similar instances of slight differences between survival in columns 2 and 3 may be similarly dismissed. The essential point that stands out regarding survival in relation to age is that in the first 5 or 6 years of the life of the seedling, each added year of age gives the seedling a little better chance to become established. This point will be observed if the data in table I above the winter of 1936-37 are compared with those below this period. Above this point in the table, the percentages of survival generally show greater differences in the different age groups than they do below this point.

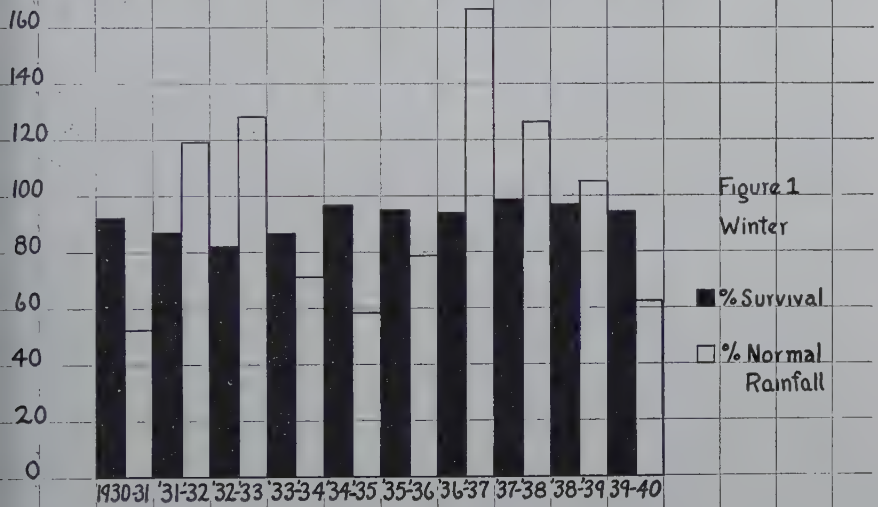
At the end of the project, 19 of the 450 first-year or 1931 seedlings were living; 101 of the 608 second-year or 1930 seedlings were living; 49 of the 155 third-year or 1929 seedlings were living. This gives a final survival of 4.22%, 16.44% and 31.61% respectively. At the end of 10 years 13.85% of the total original seedlings were still living.

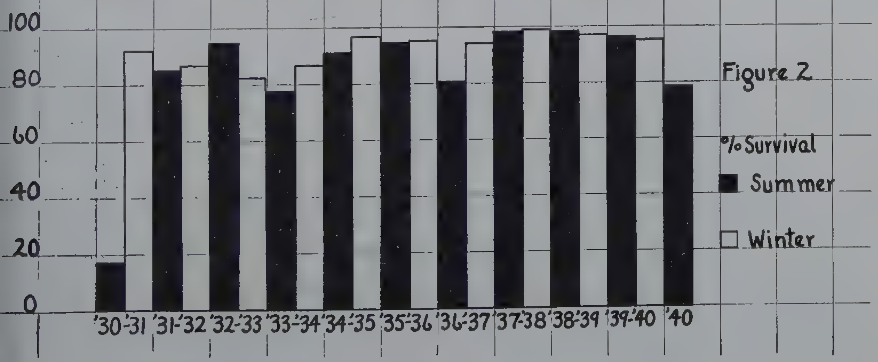
SURVIVAL AND RAINFALL

The relation of seedling survival to rainfall is shown graphically in fig. 1 where the solid columns represent percentage of survival and the empty columns represent rainfall in percentage of normal. It will be noted that there is a definite relationship between percentage of survival during the summer and percentage of normal rainfall. It will be noted that there is a definite relationship between percentage of survival during the summer and percentage of normal rainfall during the same season, during those years when the summer rainfall is below normal, e.g., summers of 1930, 1934, 1936, and 1940. This is also true for the summers when rainfall is above normal during the earlier years of life of the seedling and also when the above-normal rainfall follows a year when the summer rainfall was below normal. This will be noted in fig. 1 if 1931-1933, and 1935 are compared and if 1934 and 1935 are compared. Summer data for 1937, 1938, 1939, when the seedlings are older and when rainfall is above normal, do not show the relationship between survival and rainfall that is shown during the years 1931, 1932 and 1933 when the rainfall is also above normal but the seedlings are younger.

The extraordinarily low percentage of survival during the summer of 1930 (fig. 1) is correlated with an unusually dry season during which the soil water in the top 3 inches of soil was below the wilting coefficient during the entire months of June, July and August. This was discussed fully in our earlier paper (17) and will not be commented upon further here. Lutz (11) has shown that the initial


Percent
120
100
80
60
40
20
0
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
Figure 1
Summer
■ % Survival
☐ % Normal Rainfall


160
140
120
100
80
60
40
20
0
1930-31
'31-'32
'32-'33
'33-'34
'34-'35
'35-'36
'36-'37
'37-'38
'38-'39
39-40
Figure 1
Winter
■ % Survival
☐ % Normal Rainfall


100
80
60
40
20
0
'30-'31
'31-'32
'32-'33
'33-'34
'34-'35
'35-'36
'36-'37
'37-'38
'38-'39
'39-'40
'40
Figure 2
% Survival
■ Summer
☐ Winter

root system of hemlock is without a tap root, only laterals being present. The roots are weak and grow slowly, hence death frequently results from lack of moisture during critical periods.

Figure 1 shows no correlation between percentage of survival during the winter seasons and percentage of normal rainfall for the same seasons.

SURVIVAL IN SUMMER AND WINTER

In general the percentage of survival is lower for the summer than for the succeeding winter. This is graphically illustrated in figure 2. The most striking exception to this is found in 1932 when the percentages of normal rainfall for summer and winter are very nearly the same and both are above normal. Summer survival is a little over 12% higher than that for the succeeding winter. There are also minor exceptions in 1938 and 1939. In all of these cases the summer rainfall is above normal. The rainfall is also above normal during the winter of 1938-39 but is considerably below normal in 1939-40. It is not difficult to understand how either of the seasons may at times be more critical than the other. During the summer both available moisture and temperature are vital factors. However, on the sites under study in this case, temperature during summer would be vital only in case of deficient moisture because all of the sites were well protected from the effects of insolation. It happens that in all three of the seasons when summer survival is higher than winter, the summer rainfall is above normal. Thus, the winter environmental factors have a chance to become more critical since those of the summers in question were more nearly optimum, or at least not critical.

During the winter, temperature is more likely to be more critical than rainfall since, even when soil moisture is abundant, a frozen soil may render the soil water unavailable to the roots. Furthermore, alternate freezing and thawing would have a serious mechanical effect upon the seedling roots which are noted for their shallow penetration. The fact that hemlock seedlings occur in our area on sites with little surface litter would increase the severity of freezing and thawing of the soils. The fact that these seedlings are usually in soils a little more acid than other forest soils might have a slight mitigating influence.

GROWTH RATE IN SEEDLINGS

The ability of hemlock to hang on for long periods of time with little or no growth is well known. A consideration of the actual performance of the 168 individuals surviving after 10 years of observation bears eloquent testimony to this ability. This is shown in table III where it will be noted that the majority of the seedlings produced a height growth of from 10 to 50 cm. and a diametral growth of from 1 to 6 mm. The slowest growth recorded was that made by one seedling which attained a height of 10 cm. and a diameter of 1 mm. during the 11 years of its life. The most rapid growth recorded was that by one individual which attained a height of 76 cm. and a diameter of 17.9 mm. during the 12 years of its life. The greatest height reached by any individual was 88 cm. but this seedling attained a diameter of only 5 mm. Of the total number of survivors, 120 were growing on steep slopes under a heavy canopy of deciduous trees and 48 were in an opening on a steep north-facing slope which was well carpeted by mosses and protected from insolation by surrounding deciduous trees. On the whole, those growing in the opening made better growth than those under the forest canopy. The range of growth was greater under the forest canopy. The growth range under the forest cover was from 10 cm. in height and 1.0 mm. in diameter to 76 cm. in height and 17.9 mm. in diameter; while that in the opening was from 11 cm. in height and 1.3 mm. in diameter to 88 cm. in height and 5 mm. in diameter. The final percentage of survival among the seedlings occurring in the opening was 41.93% as compared with a survival of 13.85% for all sites.

Merrill and Hawley (14) have shown that hemlock can stand long periods of suppression as an understory tree and then grow normally when the hardwoods overhead are removed. They found that growth rate after suppression averages 2.5 times that during suppression. Zon and Scholz (21) have shown that hemlock growth increases 85% during the 20-year period following release from suppression. Lutz (11) also calls attention to the remarkable ability of hemlock to withstand suppression for long periods of time, and notes that their power of rapid recovery is remarkable. Graham (6) has shown that all hemlock seedlings which develop in shade show more or less suppression, with a minimum of 20 and a maximum of 40 year rings per radial inch. This would mean that growth rings would average 0.8 to 1.6 mm. in width. Our data in table III show the 10-year average to range from 0.1 to 1.5 mm. in diameter per year. Disregarding the fact that our measurements include both pith and bark we still have a maximum ring-width of less than 0.75 mm., which is less than one-half the minimum shown by Graham's data.

In order to secure some accurate data on width of annual rings in some of these severly suppressed seedlings, portions of two seedlings, one measuring 2.2 mm. in diameter and the other 3.3 mm., were sectioned and measured with an ocular micrometer. Sections were also taken from branches of older trees, one being near each of the seedlings. The data are presented in table II. It will be seen that ring width in the seedlings ranged from 0.042 mm. to 0.142 mm. These ring-widths vary much less than the averages cited above by Graham for suppressed seedlings. Ring-width in the branches taken from older, but still severely suppressed, trees varied from 0.142 to 0.480 mm. Griggs (7) has shown that seedlings of Sitka spruce are able to survive long periods of suppression after which they may grow vigorously to become mature trees. He relates that one tree 25 inches in diameter, with 281 rings, made only 2.5 inches in diameter during the first 35 years of its life. Allowing for pith which would also be put down during this period, the 35 year rings would have averaged about 0.8 mm. in width per ring. Comparing this with our data in table II where the maximum ring-width in the first 10 years of life of the hemlock seedlings was 0.142 mm., it again stands out that we are dealing with extreme suppression.

Evidence of complete omission of an entire year of growth is difficult to determine. It would appear from table II that seedling number 35c has omitted two years of growth. Our charts show that this seedling resulted from 1931 germination which would mean that it should have shown 10 growth rings instead of the 8 actually revealed under the microscope. Since, however, the section was taken 5 cm. above the base of the plant, it is possible that one or both of the missing rings occurred below the point where sections were taken. This seedling had attained a total height by the end of the observations of only 14.2 cm. Turberville and Hough (19) have shown that a hemlock tree, known to be 123 years old, showed 39 rings missing during the last 70 years of its life. This ability of hemlock to withstand suppression accords well with its tolerance of minimum light conditions. Burns (2) has shown that the minimum light requirements for hemlock are only a little higher than those for beech and maple. Both beech and hemlock have high abilities to withstand suppression.

SUMMARY

1. This paper reports results obtained from a 10-year survival study of hemlock seedlings under the forest conditions pertaining in a relict colony near Trevlac in Brown county, Indiana.

2. Each added year of age, other things being equal, gives hemlock seedlings a little better chance for survival.

3. When the summer rainfall is below normal, there is a definite relationship between percentage of seedling survival and percentage of normal rainfall.

4. There is a similar relationship in years when the summer rainfall is above normal during the earlier life of the seedling and also when the above-normal rainfall follows a year of below-normal rainfall, but the relationship is lacking when rainfall is above normal during later life of the seedlings.

5. There is no relationship between percentage of survival and percentage of normal rainfall during the winter seasons.

6. The percentage of survival is generally lower during the summer than during the winter, but when summer rainfalls are above normal, the winter conditions may become more critical and result in a lower percentage of survival than during the summer.

7. At the end of ten years, 13.85% of the total number of seedlings observed were still living. The original first-year seedlings showed 4.22%, the second-year 16.44% and the third-year 31.66% of the original seedlings alive.

8. The growth rate exhibited by these seedlings during the 10-year period of observation well illustrates the ability of hemlock to withstand suppression. Height range of survivors (varying from 11 to 13 years of age) was 10 to 88 cm. with a diametral range from 1 to 17.9 mm.

9. Annual rings of suppressed seedlings ranged from 0.042 to 0.142 mm. in width. Ten year average for over-all radial growth of all seedlings ranged from 0.05 to 0.75 mm. per year. This is considered to be extreme suppression.

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TABLE I

Showing percentage survival in Hemlock seedlings for 10 winters and 11 summers in relation to rainfall, expressed in inches and in per cent of normal, at Trevlac, Brown County, Indiana. Rainfall data from the Hickory Hill station.

Season	Seedlings alive beginning of season			Percentage survival			Percentage Survival	Rainfall	
	1st yr.	2nd. yr.	3rd. yr.	1st yr.	2nd yr.	3rd yr.	Total	Inches	% Normal
Summer[1] 1930	60	74		11.67	21.62		17.20	10.20	47.36
Winter[2] 1930-31	158	191	21	88.61	95.29	95.25	92.43	9.79	52.49
Summer 1931	172	224	30	82.97	87.06	90.00	85.45	27.07	124.94
	1931	1930	1929	1931	1930	1929			
Winter 1931-32	304	446	145	74.34	90.37	89.65	87.37	22.34	119.82
Summer 1932	265	443	133	92.46	95.94	96.24	94.89	29.02	130.89
Winter 1932-33	264	446	126	77.28	82.96	90.56	82.30	24.40	128.90
Summer 1933	199	379	117	64.32	81.53	87.18	77.56	22.74	102.57
Winter 1933-34	126	302	106	83.33	87.08	89.62	86.70	13.37	71.69
Summer 1934	97	248	93	86.66	91.93	93.55	91.55	21.47	96.84
Winter 1934-35	86	232	83	94.19	95.74	100.00	96.75	10.82	58.02
Summer 1935	72	223	81	89.66	95.55	97.53	94.68	25.23	113.81
Winter 1935-36	69	218	79	89.85	96.79	92.40	95.58	14.90	79.89
Summer 1936	62	211	73	67.74	82.94	84.91	80.63	16.42	74.06
Winter 1936-37	42	166	62	88.09	94 00	98.30	94.07	31.16	167.08

TABLE I (Continued)

Showing percentage survival in Hemlock seedlings for 10 winters and 11 summers in relation to rainfall, expressed in inches and in per cent of normal, at Trevlac, Brown County, Indiana. Rainfall data from the Hickory Hill station.

Season	Seedlings alive beginning of season			Percentage survival			Percentage Survival	Rainfall	
	1st yr.	2nd. yr.	3rd. yr.	1st yr.	2nd yr.	3rd yr.	Total	Inches	% Normal
Summer 1937	37	156	61	97.30	98.08	98.36	98.03	26.91	121.37
Winter 1937-38	36	153	60	97.22	98.69	98.33	98.39	23.56	126.33
Summer 1938	35	151	59	100.00	97.35	100.00	98.59	22.64	102.12
Winter 1938-39	35	147	59	94.28	97.28	98.31	97.10	19.66	105.42
Summer 1939	33	143	58	100.00	94.40	98.27	96.15	24.63	111.10
Winter 1939-40	33	135	57	93.93	96.30	92.98	95.11	11.63[3]	62.36
Summer 1940	31	130	53	61.29	77.10	92.46	78.51	18.88[4]	85.16
Final Survival	19	101	49	4.22	16.44	31.61	13.85		

1. Summer=April-September
2. Winter=October-March
3. Due to closing of the Hickory Hill station, data for January-March 1940 were taken from the Columbus station which is approximately 25 miles from the location of the seedlings.
4. Data for summer 1940 taken from the Kelly Hill station.

TABLE II

Comparing radial growth of 2 severely suppressed seedlings with that of branches from nearby older trees. Diametral measurement of seedling was taken 5 cm. above the ground.

	% Normal Rainfall		Growth in Radius			
Year	Summer	Winter	Seedling 16A 42 cm high 3.3 mm dia.	Branch of Tree near 16A 2.2 m high	Seedling 35C 14.5 cm high 2.2 mm dia.	Branch of Tree near 35C 6 m high 7 cm dbh
1940	85.16		0.09 mm	0.382 mm	0.042 mm	0.162 mm
1939	111.10	62.36	0.142	0.480	0.070	0.218
1938	102.12	105.42	0.114	0.462	0.046	0.214
1937	121.37	126.33	0.098	0.416	0.048	0.264
1936	74.06	167.08	0.108	0.392	0.056	0.336
1935	113.81	79.89	0.128	0.344	0.078	0.354
1934	96.84	58.02	0.066	0.296	0.050	0.268
1933	102.57	71.69	0.128	0.248	0.118*	0.244
1932	130.89	128.90	0.11			0.192
1931	124.94	119.82	0.11			0.172
1930	47.36	52.49	0.146*			0.142
1929	111.17	87.02				0.324

*Measurement included medulla. Xylem formed was approximately one-half of this measurement.

TABLE III

Showing size classes by height and diameter of all seedlings surviving at end of 10-year period

Height Classes	Diameter Classes in mm 1-1.9	2-2.9	3-3.9	4-4.9	5-5.9	6-6.9	7-7.9	9-9.9	12.4	17.9
5- 9 cm	3									
10-14	10	8	1							
15-19	20	13	3							
20-24	14	18	2	5						
25-29	4	12	11							
30-34	1	7	4	2	1					
35-39	1	1	2	6						
40-44			3	1	2	2				
45-49					2					
50-54		1								
55-59							2		1	
60-64				1						
65-70							1			
75-79										1
80-84								1		
85-89					1					
Total	53	60	26	15	6	2	3	1	1	1

Total Seedlings surviving 10-year period—168 or 13.85%

THE VEGETATION OF ROUND ISLAND (STRAITS OF MACKINAC), MICHIGAN

By J. E. Potzger

The vegetation of Round Island was studied briefly during the summers of 1935 and 1936 while an extensive survey was in progress on Mackinac Island (5). Round Island is 0.5 miles southeast of Mackinac, separated from it by the Straits of Mackinac. It comprises several hundred acres of land surface (1.5 by 0.75 mile) most of which consists of a thin layer of soil over a limestone substratum. The central part of the island is considerably higher above lake level than the outer rim, but perhaps not exceeding 50 feet. Several ancient beaches are in evidence along the shore but they are not so extensive as on Mackinac. The present beach is wide and strewn with abundant granite and quartzite boulders. The peninsula-like northern tip is evidently subjected to extreme wave action, hence has a sparse vegetation.[1]

CULTURAL INFLUENCES

While Round Island is uninhabited except for the keeper of the lighthouse and his family, it has not been spared the destructive influence of civilized man. The entire central hardwoods stand was cut for firewood by citizens of neighboring islands, as the small stem sizes and abundance of trees in table II well reflect. The coniferous forest fared better in the past in this respect than the hardwoods.

OBSERVATIONS

The distributional features of the forest are almost a counterpart of those found on Mackinac, viz. an outer belt of coniferous forest composed primarily of *Picea glauca*, *Abies balsamea* and *Thuja occidentalis* surrounding a central stand of northern hardwoods. Thuja has highest abundance of all species in the peripheral zone, except at a rather low lying upper beach along the northern shore.

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[1] Sincere appreciation is expressed to Mr. C. R. Nennert of Indianapolis for assistance given in the field work.

Here *Pinus resinosa, P. strobus,* associated with *Abies balsamea* are chief contenders for control in the crown cover. A large number of woody species participates in the association of the coniferous forest, i.e. 18 (table I) over against 8 in the broadleaved forest (table II). It is a striking feature that Abies is the only conifer represented among the tree species constituting the broadleaved forest.

Along the wide rock beach, reproduction of woody species is prolific. In a sample quadrat, five by ten meters, was found the following representation: *Picea glauca* 62 (7 stems one to two inches DBH.), *Thuja occidentalis* 21 (3 stems one to two inches DBH.), *Pinus strobus* 2, *Larix laricina* 13, *Abies balsamea* 4, *Populus tacamahacca* 1, *Hypericum kalmianum* 56, *Prunus pumila* 1, *Shepherida canadensis* 6, *Potentilla fruticosa* 12, a total of 180 stems.

Three samples of surface soil along the shore gave a range in pH of 6.72 to 8.21 which, also, is similar to the soil on Mackinac Island. The representative sample plot on reproduction in bare areas further bears out that succession is short, or perhaps it were better to say, is wanting, for the seedlings of the dominants become established immediately. The 84 species of plants, involving 29 families, collected during two days in the month of August are perhaps less than half the total number present during the various seasonal aspects.

LIST OF SPECIES

Aceraceae: *Acer pennsylvanicum* L., 7306.* *A. saccharum* Marsh, 7206, *A. spicatum* Lam., 6558.

Betulaceae: *Betula papyrifera* Marsh, 7294. *Corylus cornuta* Marsh, 7270. *Ostrya virginiana* (Mill.) K. Koch, 7305.

Campanulaceae: *Campanula rotundifolia* L., 6537.

Caprifoliaceae: *Virburnum trilobum* Marsh, 7306a.

Compositae: *Anaphalis margaritacea* var. *intercedens* Hara, 7280. *Artemisia caudata* Michx., 6563. *Aster pilosus* var. *pringlei* (Gray) Blake, 6540. *Coreopsis lanceolata* L., 7269. *Eupatorium maculatum* L., 7273. *Rudbeckia hirta* L., 7272. *Solidago altissima* L., 6541. *S. gilmani* (Gray) Steele, 6564. *S. graminifolia* (L.) Salisb., 6548. *S. hispida* Muhl., 6542. *S. ohioensis* Riddell, 6549.

Cornaceae: *Cornus canadensis* L., 6559. *C. stolonifera* Michx., 7263. *C. rugosa* Lam.

Cyperaceae: *Scirpus validus* Vahl., 7261.

Elaeagnaceae: *Shepherdia canadensis* (L.) Nutt., 7258.

Ericaceae: *Arctostaphylos uva-ursi* var. *coactilis* Fern., 7262.

Fagaceae: *Fagus grandifolia* Ehrh., 7304.

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*The numbers refer to the author's field collection records.

Gentianaceae: *Gentiana procera* Holm., 6565. *Halenia deflexa* (Sm.) Griseb., 6544.

Geraniaceae: *Geranium Robertianum* L., 7253.

Gramineae: *Agropyron repens* (L.) Beauv., 7286. *Agrostis alba* L., 7288. *A. scabra* Willd., 6539. *Calamagrostis canadensis* (Michx.) Beauv., 7274. *Cinna latifolia* (Trev.) Griseb., 7301. *Deschampsia caespitosa* (L.) Beauv., 7285. *Elymus canadensis* L., 7283. *Hystrix patula* Moench, 6567. *Milium effusum* L., 7298. *Panicum tennesseense* Ashe, 6554. *Phalaris arundinacea* L., 7287. *Poa compressa* L., 7290. *palustris* L., 7281.

Hypericaceae: *Hypericum kalmianum* L., 6552. *H. perforatum* L. 7282.

Juncaginaceae: *Triglochin palustris* L., 7264.

Labiatae: *Satureja glabra* (Nutt.) Fern. 6551.

Liliacae: *Clintonia borealis* (Ait.) Raf., 6557. *Smilacina stellata* (L.) Desf., 7275. *Streptopus roseus* Michx., 7279. *Zygadenus glaucus* Nutt., 6543.

Lobeliaceae: *Lobelia kalmii* L., 6538.

Lycopodiaceae: *Lycopodium annotinum* L., 6556. *L. lucidulum* Michx., 7303.

Ophioglossaceae: *Botrychium virginianum* (L.) Sw., 7299.

Orchidaceae: *Goodyera pubescens* (Willd.) R. Br., 7291.

Pinaceae: *Abies balsamea* (L.) Mill., 7254. *Juniperus communis* var. *depressa* L., 7277. *J. horizontalis* Moench, 7256. *Larix laricina* (DuRoi Koch, 7255. *Picea glauca* Voss, 7293. *Pinus strobus* L., 7267. *P. resinosa* Ait. *Taxus canadensis* Marsh, 6546. *Thuja occidentalis* L., 7257.

Polypodiaceae: *Adiantum pedatum* L., 7300. *Cystopteris bulbifera* (L.) Bernh., 7297. *Dryopteris marginale* (L.) Gray, 7295. *Dryopteris spinulosa* (O. F. Muell.) Ktze., 6568.

Primulaceae: *Primula farinosa* var. *armericana* Torr., 7289. *Trientalis borealis* Raf., 6560.

Ranunculaceae: *Anemone multifida* Poir., 6566.

Rosaceae: *Amelanchier canadensis* (L.) Medic., 7268. *Physocarpus opulifolius* (L.) Maxim, 7259. *Potentilla anserina* L., 7278. *P. fruticosa* L., 6553. *Sorbus americana* Marsh, 6562.

Salicaceae: *Populus tacamahacca* Mill., 7307. *P. tremuloides* Michx., 7260. *P. grandidentata* Michx.

Saxifragaceae: *Mitella nuda* L., 6561.

Scrophulariaceae: *Castilleja coccinea* (L.) Spreng., 6550. *Gerardia tenuifolia* Vahl., 6547. *Linaria vulgaris* Hill., 7277. *Melampyrum lineare* Lam., 6545.

DISCUSSION

Vegetation on the smaller islands in the Great Lakes, located within the center of the lake forest climax region, shows plainly the stress between the replaced boreal forest and the recently invading northern hardwoods. The more rigorous microclimate along the periphery of islands limits invasion and replacement of boreal forest complexes by the broadleaved southern species to the more protected central parts of small land masses, as Mackinac (5) and Round Island demonstrate. This sharp segregation into the two associations along sharply defined limits, with the absence of the intermediate pine association, becomes mode modified on larger islands, as shown by Darlington (2) for Beaver Island. Here one finds distribution of forest types with merging characteristics like those of the mainland of Michigan, i.e. pine constituting the chief forest cover on sandy soil, northern hardwoods, associated with Tsuga, dominating in habitats where soil is clay or loam; while Abies, Picea, Larix, and Thuja express the more hydrophytic bog and swamp habitats, as described in detail by Gates (3, 4) for the Douglas Lake region.

This makes it difficult at times to define the climax status of an area, for two climax formations on small islands are sharply separated along narrow geographical lines. However, the author agrees with Cooper (1) that *Acer saccharum* demands climax control wherever it occurs, as is well shown by the central section of Round Island (table II), and the peripheral association of conifers must be considered post-climax. The two forest types are much more sharply separated on Round Island than on Mackinac (5). In the latter location conifers constitute 25% of the trees in the broadleaved forest while on Round Island only Abies has a small representation in the seedling stem sizes (table II). The writer is, however, now more firmly convinced than in 1941 (5) that Acer-Fagus is the climatic climax and conifers are post-climax for Mackinac also, in spite of the fact that Fagus and Acer there are suffering from rigors of the climate, and that conifers still occupy a prominent place under the poorly developed crown cover of the northern hardwoods association.

On Round Island as well as on Mackinac we are without doubt dealing with calciphilous ecotypes of certain phenotypes, for Thuja, *Picea glauca, Abies balsamea, Larix laricina, Potentilla fruticosa* reproduce readily in alkaline soil, while on the mainland of lower Michigan they are typical bog species (See Gates, 4). The general alkalinity of soil is also shown by the total absence of shrubby ericads and *Pinus banksiana.*

For the final determination as to whether the coniferous or broadleaved forest expresses microclimatic control one must perhaps consult pollen records as to great successional tendencies during past ages. The record from Douglas Lake by Wilson and Potzger (6), 30 miles south of the Straits, shows an early undisputed dominance by *Picea glauca* and Abies which was in turn replaced by Pinus, and this again gave way to broadleaved complex, so that we must define maple or beech-maple as climax for Round Island with coniferous forest as post-climax, the latter maintained by the more rigorous microclimate along the periphery of the island habitat.

SUMMARY

1. Presented in this paper are data of an ecological survey of the forest on Round Island, Michigan.

2. The central part of the island is controlled by northern hardwoods, primarily by an Acer consociation, and the periphery by spruce-fir-arbor vitae.

3. A partial list of species (84) constituting the vegetation is given, and while it is fairly complete for woody species, the record favors the summer phase of the herbaceous plants.

4. The soil along the exposed beach is highly alkaline.

5. Ericads are represented only by Arctostaphylos.

6. Tree species in the central hardwoods area with highest F. I. are: *Acer saccharum,* 100; *Betula papyrifera,* 40; *Populus tacamahacca,* 40; *Abies balsamea,* 60.

7. Tree specias with highest F. I. in the fringing belt of conifers are: *Thuja occidentalis,* 92; *Abies balsamea,* 92; *Picea glauca,* 85; *Betula papyrifera,* 46; *Amelanchier canadensis,* 61.

8. Species with greatest abundance in the hardwoods are: *Acer saccharum, Populus tacamahacca, Betula papyrifera, Abies balsamea.*

9. The association of species is more simple in the hardwoods than in the coniferous forest.

10. It is concluded that hardwoods are climax for Round Island and conferous forest post-climax, maintained by a more rigorous microclimate along the periphery of islands.

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TABLE I

Abundance by size classes and F. I. of woody species participating in the forets complex of the northern hardwoods in the central part of Round Island, Michigan. Based on five 100-square-meter quadrats.

Species	Below 1 inch	1-2 inches	3-5 inches	6-10 inches	11-15 inches	16-20 inches	Total stems over 1 in.	F. I.
Abies balsamea	24	4					4	60
Acer saccharum		11	17	18	2		48	100
Betula papyrifera				3	6		9	40
Acer spicatum	28	9					9	40
Amelanchier canadensis	7							40
Sambucus sp.?	4							20
Populus tacamahacca					5	2	7	40
Sorbus americana				1	1		2	20
Taxus canadensis	2							20

TABLE II

Abundance by size classes and F. I. of woody plants participating in the forest along the outer rim of Round Island, Michigan. Based on 13 100-square-meter quadrats.

Species	Below 1 inch	1-2 inches	3-5 inches	6-10 inches	11-15 inches	16-20 inches	Total stems 1 in. or over	F. I.
Abies balsamea	57	43	40	11			94	92
Picea glauca		8	24	13	2		47	85
Thuja occidentalis	21	52	115	56	6		229	92
Amelanchier canadensis	14	32	6				38	62
Larix laricina	3							8
Betula papyrifera		2	10	5			17	46
Pinus resinosa		3	8	7	1	1	20	31
Pinus strobus		1	1	4	1		7	15
Acer saccharum		1	2	3			6	23
Populus grandidentata			3	4			7	31
Acer spicatum	1	1					1	8
Taxus canadensis	22							38
Corylus cornuta	39							38
Populus tacamahacca	5							8
Cornus rugosa	9	1					1	8
Viburnum acerifolium	2							8
Cornus stolonifera	1							8

POLLEN FREQUENCY OF ABIES AND PICEA IN PEAT: A CORRECTION ON SOME PUBLISHED RECORDS FROM INDIANA BOGS AND LAKES

By J. E. Potzger

An error was introduced in a number of reports on pollen profiles from Indiana bogs and lakes because Picea and Abies were separated on basis of size as presented in a key by Sears (19), which included only *Picea mariana* but not *Picea glauca*. Unfortunately we had no pollen of *Picea glauca* in the laboratory when work was begun and so the important comparison with modern pollen was neglected, with the result that the error in identification of the two genera appeared in all early publications dealing with pollen studies from Indiana.

The writer expresses thanks to Dr. L. R. Wilson for drawing attention to the difference in size of the pollens from *Picea mariana and Picca glauca,* as well as to the fact that Abies pollen is usually smaller than that of *Picea glauca,* and cannot be separated by the size characteristics given in the above-mentioned key.

The check of the error was made comparatively easy because we not only store the sealed bottles of all peats collected (in their natural moist condition), but we also have a complete file of all slides used for the original pollen counts. Included in the re-count were as many pollen grains from spruce and fir as the two general totalled in the percentage figures of the published papers. A complete list of these papers is included in the bibiography. Only pollens of Picea and Abies were considered, hence, all other genera are credited with representation as reported in the original graphs and tables. (Tables 1 and 2).

The short article by Potzger (10) contained only one level report on pollen frequency and so did not adapt itself well to be included in the tables. The corrected percentage representation is as follows: Abies 9, Picea 65.

In the papers by Smith (20) and Otto (9) it was erroneously claimed that Tsuga pollen preserves poorly when wet. Sears (19) reports this characteristic for Thuja but not for Tsuga.

The percentage figures on Abies and Picea pollens in papers by several other workers indicate that they differentiated between the two genera according to the same key which made us err in our early reports. In these papers Abies is credited with a higher representation than Picea. This appears to be the case in the studies by Artist (1), Hansen (4), Houdek (6), and Voss (23). In a later paper Voss (22) records Picea as exceeding Abies greatly in pollen frequency, agreeing there with results shown in more recent publications. In our own studies in Indiana (7, 10, 12), Minnesota (25), Wisconsin (11, 15), Michigan (24), and New Jersey (14) we found Abies seldom attaining a frequency of 20 per cent at any one foot-level. Data of studies covering such a wide range of geographical locations are perhaps sufficiently representative for the glaciated area of the central and northeastern United States to warrant the assumption that Abies was not so abundant as Picea, and in general has a much lower pollen frequency in bog and lake sediments than *Picea glauca,* as all more recent papers bear out.

TABLE II

Recount on pollen of Abies and Picea in sediments from 8 Indiana bogs and lakes to correct an error in published reports on the bogs and lakes considered in the table. Figures in parentheses after name of bog or lake refer to papers listed in the bibliography

	Winona Lake (16)		Third Sister L (16)		Kokomo Bog (5, 13)		Cranberry Pond (2, 13)		Bacons Swamp (9, 13)		Lake Cicott (13, 20)		Yountsville (21)		Altona Bog (8)	
Foot Level	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea
5													2	7		
6										1			2	7		
7										½				4		
8										1½				2		
9									½	1				25		
10										1			8	29		
11										½			5	24		
12									4	12			14	50		
13										16			14	70		
14										10			8	74		
15			1	3						4			7	78		
16			1	10						12			12	79		
17			1	2				1	2	14			9	80		
18			1	85				1	4	14			11	79		
19				65	1	6		3	4	26			4	90		3

TABLE II (Continued)

Recount on pollen of Abies and Picea in sediments from 8 Indiana bogs and lakes to correct an error in published reports on the bogs and lakes considered in the table. Figures in parentheses after name of bog or lake refer to papers listed in the bibliography

	Winona Lake (16)		Third Sister L. (16)		Kokomo Bog (5, 13)		Cranberry Pond (2, 13)		Bacons Swamp (9, 13)		Lake Cicott (13, 20)		Yountsville (21)		Altona Bog (8)	
Foot Level	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea
20			3	76	2	18	1	2	5	75			4	89		2
21				65	2	11	8	6	8	74	4	3	1	92		4
22			2	64	3	78	1	11	5	89	1	4	9	78	5	26
23			4	76	6	72	2	3	5	82	1	2	5	84	4	92
24			4	81	5	86	3	15	4	91	5	5	1	86		
25			5	87	6	84	2	39	4	90	5	12				
26			x	xx	4	88	3	62	2	94	7	17				
27	2	16	x	xx	5	87	6	75	10	85	4	23				
28		16	x	xx	4	93	4	67	4	90	2	35				
29	4	40	x	xx	3	93	3	73	3	94		40				
30		91	x	xx	4	94	2	90	3	97	2	52				
31		96	x	xx	2	94	6	80	4	89	10	81				
32		98	x	xx	6	88	8	85	6	90						
33	1	96		96												

TABLE I

Recount on pollen of Abies and Picea in sediments from 8 Indiana bogs and lakes to correct an error in published reports on the bogs and lakes considered in the table. Figures in parentheses after name of bog or lake refer to papers listed in the bibliography

	Tippecanoe (16)		Mill Creek (21)		Otterbein (13, 18)		Silver Lake (8)		Fox Prairie (13, 17)		Round Lake (3)		Matthews Bog (13)		Lakeville (3)	
Foot Level	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea
22													2	4		
23		½											8	30		
24										4			2	8		4
25									6	5	1	4	2	74		--
26									4	10		5½	3	77		—
27	2½	11½							2	16	6	3		81	3	6
28	1	14½							4	9	3	7	3	87	14	21
29	3	13			1	1			1	4	7	58	1	95	33	62
30	2	40							4	7	4	81				
31	2½	34½					1	3		10	4	80				
32	2	30½			1	2	4	9	2	41	8	85				
33	2	26		2	3	10	8	23	4	72						
34	3	28½			1	9	11	36	6	84						
35		50		1	5	70	11	45	2	94						
36	2	88			7	61	8	83	4	93						
37	—	88			1	63	5	94	1	96						
38	8	84			1	76	2	96	3	97						
39	6	85		1	4	79	1	98		100						
40	6	89			2	72	10	90								

TABLE I (Continued)

Recount on pollen of Abies and Picea in sediments from 8 Indiana bogs and lakes to correct an error in published reports on the bogs and lakes considered in the table. Figures in parentheses after name of bog or lake refer to papers listed in the bibliography

	Tippecanoe (16)		Mill Creek (21)		Otterbein (13, 18)		Silver Lake (8)		Fox Prairie (13, 17)		Round Lake (3)		Matthews Bog (13)		Lakeville (3)	
Foot Level	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea	Abies	Picea
41	8	87			1	91		100								
42	5	91				93										
43	2	85				82										
44	10	86		3	3	90										
45	7	86	2	4												
46	8	64	3	11												
47	6	74	8	39												
48	—	—	11	17												
49	—	95	17	20												
50	—	—	22	26												
51	8	88	2	28												
52	—	—	4	81												
53	6	46	7	89												
54	—	—	1	92												
55	—	—	3	95												
56	—	—	5	92												
57	—	—	6	85												
58	—	—	5	91												
59	10	80	5	93												

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NOTES ON DISTRIBUTION AND BIO-ECOLOGY OF CHARACEAE IN NEBRASKA*

By Walter Kiener

INTRODUCTION AND ACKNOWLEDGMENT

The species of the family Characeae have for many years been generally neglected by botanists leaving identification a difficult matter due to the absence of usable and practical keys and descriptions. Because of this difficulty to correctly identify species, field workers, particularly those in wildlife research, further neglected the study of the ecology of the species. Most workers lumped the species together as though they were all alike. This resulted in much ambiguity when species of Characeae were under consideration.

It was a good fortune when in 1943 Fay Kenoyer Daily began to study this family and was backed by the facilities of the Botany Department of Butler University. All collections of Characeae made in Nebraska were sent to her and she made all the identifications. These are the accepted ones for this work. Without her help and the facilities of Butler University this work could not have been carried on and whatever progress is registered in the following pages is due to her cooperation and that of Butler University. The result of her own work is published simultaneously in this issue and the reader is referred to this for more details of the geographic distribution of the Characeae and their taxonomic status (4). For courtesy and opportunity to study the collections, credit is due Dr. L. B. Walker, curator of the herbarium of the University of Nebraska.

HISTORICAL RECORDS AND THEIR DISTRIBUTION

In a catalogue of the flora of Nebraska, in 1890, Webber (9) lists *Chara coronata* as being "very common in the ponds of central and western Nebraska," and gives as localities Thedford in Thomas Co., and Belmont and Ft. Robinson in Dawes Co. *Chara* sp. occurred "in ponds usually with the preceding." *Nitella opaca* is listed as occurring "in small, stagnant ponds, Lincoln, May 5, 1890. A medium sized dioecious species found in considerable quantity by Mr. Shimek of the state university."

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* This is a joint contribution from the Pittman-Robertson Division of the Nebraska Game, Forestation and Parks Commission, L. L. Mohler, supervisor, Paul T. Gilbert, executive secretary; University of Nebraska, Conservation and Survey Division, G. E. Condra, dean and director; and Butler University, Botany Department, Ray C. Friesner, chairman.

In an appendix to the catalogue of 1892, Webber (10) lists *Chara contraria* as occurring in "flowing or standing water and cold springy lakes," and gives one locality namely Fremont in Dodge Co., and collected by Williams. *Chara fragilis* is listed as occurring "in ponds." The localities given for this species are Greeley Center in Greeley Co., Greenwood in Cass Co., and Fremont in Dodge Co., this latter being collected by Williams. *Nitella acuminata* var. *glomerata* is listed from "ponds near Lincoln (Bessey)," Lancaster Co. *Nitella flexilis* is listed as from "ponds near Minden," Kearney Co. *Nitella mucronata* is also listed from "ponds near Minden." Both these plants were "in material collected by Dr. Hapeman (Bessey)."

In a supplementary list, also in 1892, Bessey (1) reports *Chara foetida* "collected by J. M. Bates at Valentine," Cherry Co.

The report on collections made in 1892 by the Bot. Surv. of Nebr. (7) lists *Chara fragilis* "in a small lake, Cherry Co., July 19." *Chara contraria* is listed from "ponds in wet valleys, Cherry Co., July 17, 18." *Chara foetida* var. *longibracteata* is listed from "ponds in wet valleys, Sheridan Co., July 12, 13." *Chara coronata* is listed as occurring "in small lake, Cherry Co., July 18."

The report for 1893 of the Bot. Surv. of Nebr. (2) gives no information other than localities and lists *Nitella translucens* as from York, York Co. *Nitella translucens* form *confervoides* is also from York. *Chara crassicaulis* is reported from Haigler in Dundy Co., and Pine Ridge, presumably Dawes Co. *Chara evoluta* is listed from Sheridan Co. as part of material reported as *C. foetida longibracteata* in 1892, *Chara sejuncta* is listed from Minden, Kearney Co.

The year 1894 brought the illustrated paper on Characeae by Woods (11). He gave detailed descriptions and illustrations of the following species, *Nitella subglomerata, N. flexilis, N. opaca, N. mucronata,* and *N. translucens, Chara coronata, C. contraria, C. foetida, C. crassicaulis, C. evoluta, C. fragilis,* and *C. sejuncta.* This makes twelve species for the state of which several had subspecies named. For about half of these species, Woods does not mention any habitat, and for the others only with insufficient curtness. The localities from which the collections were made are stated but cursorily. No collections were named and herbarium specimens were cited only in few cases and these very meagerly. Woods neither stated whether the illustrations were all original drawings from Nebraska specimens or were adapted from other works. All species reported on by Woods, had previously been recorded in the works cited above. As nearly as can be made out, Woods had apparently twenty-five herbarium records available for his study of the twelve species he listed at that early date of botanical exploration in Nebraska. His determinations were remarkably accurate for that time. A culminating point was reached in the study of Characeae in Nebraska. For half a century interest in this group of plants nearly ceased. Seldom was a species named in the literature, and equally seldom did a specimen find its way into the herbarium. The number of collections rose from twenty-five to fifty-eight. It remains a great pity, however, that the locations from which these collections came were so poorly stated that they can not be re-located to ascertain any possible changes in the vegetation during this long interval.

In 1897 and 1900 Pound and Clements (6) had their work on the phytogeography of Nebraska published. Their short statements regarding distribution and occurrence of Characeae were apparently based on the paper by Woods, which due to insufficient material and observation were bound to be erroneous in many respects.

COLLECTION RECORDS AND THEIR DISTRIBUTION

For the study of Characeae there are now available at the University of Nebraska two groups of collections. For convenience the collection of the writer will be referred to as the Kiener collection and that of the herbarium of the University of Nebraska as the herbarium collection.

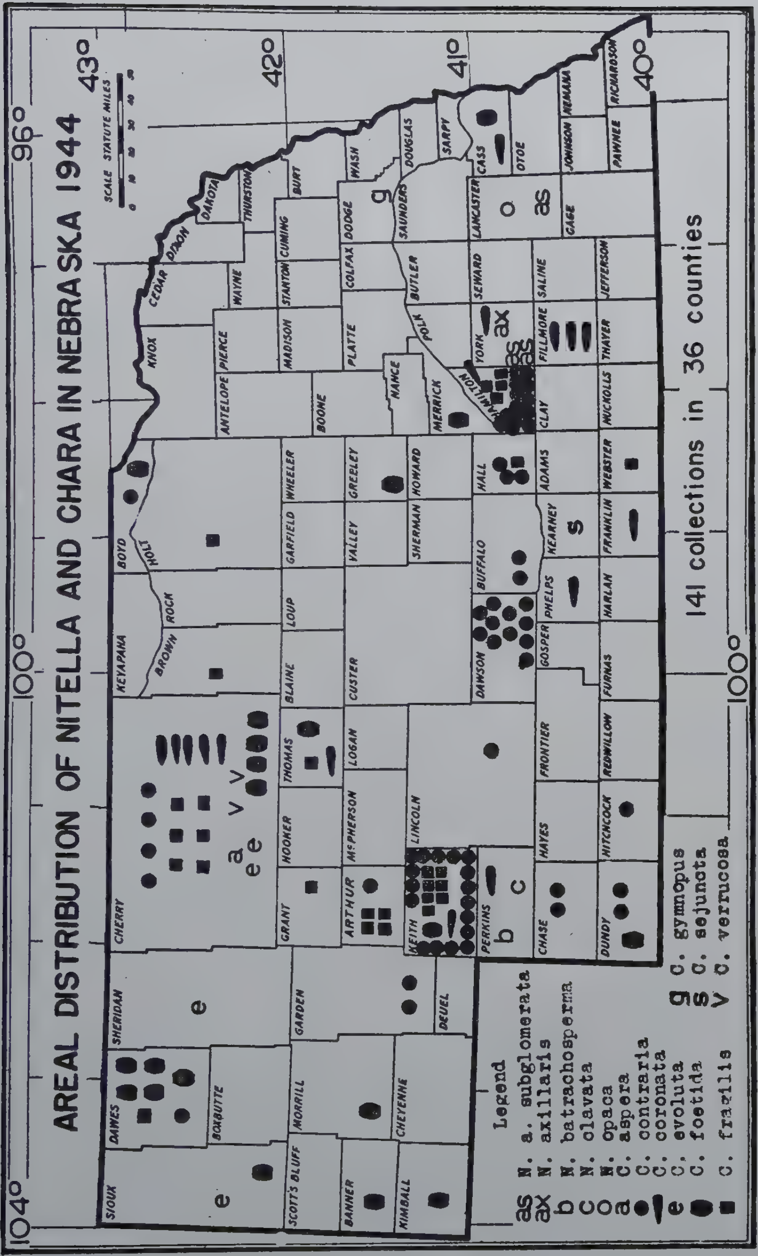
THE HERBARIUM COLLECTION. The number of collections in the university herbarium increased from the twenty-five Woods had at his disposal in 1894 to fifty-eight by 1941. This small accruement in nearly fifty years remained however practically unidentified until 1944 when Fay Kenoyer Daily (4) revised and identified the whole collection. At this date the herbarium collection of fifty-eight single collections was made by sixteen collectors from twenty-one counties and contained eleven species as now recognized. From certain indications it may be assumed that few of these collectors were particularly interested in Characeae and all the collections were thus more or less incidental.

The Kiener collection. The writer collected the first specimens of Chara in Nebraska incidentally during fieldwork in the summer of 1941 in the southwestern counties which make up the Republican River watershed. This work was done under the auspices of the Conservation and Survey Division of the University of Nebraska. In the summer of 1943 and through the winter to the spring of 1944, Characeae was studied advisedly. Specimens were collected for biological and taxonomical reasons during a preliminary investigation of aquatic communities in the counties along the Platte River in central Nebraska. This work was done under the auspices of the Pittman-Robertson Division of the Nebraska Game, Forestation and Parks Commission. Eighty-three collections from sixteen counties and representing seven species were obtained through the different seasons of this field work.

Comparison of the Two Collections. Certain features of interest become apparent when the two groups of collections are compared. For analysis the herbarium group may be subdivided into an early and late subgroup. The early subgroup includes the twenty-five species Woods had available and identified by 1894. In *Chara* he listed seven species, one of which (*C. crassicaulis*) is not now recognized as being represented. These early collections were fairly scattered over the state and already represented the main species of this genus. In *Nitella* Woods listed five species, two of which have not been substantiated, and of which two others appear with a change in nomenclature. The second subgroup, comprising the collections from 1894 to 1941, added two more species to those listed by Woods. No species of Nitella were collected during this period. The sixteen collectors, sampling twenty-one counties out of ninety-three in Nebraska, obtained in fifty-eight collections an apparently fair random sample of the species of Characeae present in the state and their approximate geographical distribution. As now recognized there were eight species of *Chara* and three of *Nitella*.

In contrast, the Kiener collection was not made to obtain a geographic random sample, but (a) to establish sociological relations of aquatic communities, and (b) to gain biological information on the species of Characeae. The interest was wholly ecological and many collections were made from the whole extent of a single habitat such as a lake or pond, and at different times of the year. Geographically

PLATE I


AREAL DISTRIBUTION OF NITELLA AND CHARA IN NEBRASKA 1944
104°
100°
96°
43°
42°
41°
40°
SCALE STATUTE MILES
0 10 20 30 40 50
SIOUX
DAWES
SHERIDAN
CHERRY
KEYAPAHA
BROWN
ROCK
BOYD
HOLT
KNOX
CEDAR
DIXON
DAKOTA
THURSTON
WAYNE
PIERCE
ANTELOPE
BOXBUTTE
SCOTT'S BLUFF
MORRILL
GARDEN
GRANT
HOOKER
THOMAS
BLAINE
LOUP
GARFIELD
WHEELER
BOONE
MADISON
STANTON
CUMING
BURT
BANNER
KIMBALL
CHEYENNE
DEUEL
KEITH
ARTHUR
McPHERSON
LOGAN
CUSTER
VALLEY
GREELEY
NANCE
PLATTE
COLFAX
DODGE
WASH
DOUGLAS
SARPY
SAUNDERS
BUTLER
POLK
LINCOLN
SHERMAN
HOWARD
MERRICK
HAMILTON
YORK
SEWARD
LANCASTER
CASS
OTOE
PERKINS
DAWSON
BUFFALO
HALL
ADAMS
CLAY
FILLMORE
SALINE
GAGE
JOHNSON
NEMAHA
RICHARDSON
PAWNEE
JEFFERSON
THAYER
NUCKOLLS
WEBSTER
FRANKLIN
KEARNEY
PHELPS
GOSPER
FRONTIER
HAYES
CHASE
DUNDY
HITCHCOCK
REDWILLOW
FURNAS
HARLAN
141 collections in 36 counties
Legend
as N. a. subglomerata
ax N. axillaris
b N. batrachosperma
c N. clavata
o N. opaca
a C. aspera
● C. contraria
▮ C. coronata
e C. evoluta
● C. foetida
■ C. fragilis
g C. gymnopus
s C. sejuncta
v C. verrucosa

these eighty-three collections were made from sixteen counties. They represent five species of *Chara,* one of which was new to the state record and two species of *Nitella,* both of which were also new records. By coincidence, fifteen of the sixteen counties of the Kiener collection were not represented by the herbarium collection, thus forming a considerable extension in area. Altogether the record of Characeae for Nebraska, available at this time, consists of 141 collections from thirty-seven well-scattered counties. *Chara* is now represented by nine species and *Nitella* by five. The addition of these eighty-three collections to the fifty-eight of the herbarium added only three rare species to the record as each of these was found only once. It is of considerable interest to note that by more than doubling the number of collections, and nearly doubling the number of counties from which collections were made, the knowledge of the geographic distribution of the members of this family was not materially altered. A good, geographic random sample had been obtained by the many collectors, gathering a modest number of collections from widely spaced counties. From this it may be assumed that the number of further additions will be interstitional and probably small. Plate I and tables 1 and 2 analyze and summarize the geographic distribution of the species in the state. It shows three trends in geographical distribution. *Chara coronata* has a more pronounced presence in the southern counties, due probably to the intermittent pools of the table lands; *Chara contraria* has the greatest presence in the Platte River Valley, due no doubt, to the gravel-pit ponds; and *Chara fragilis* and *Chara foetida* have their greatest presence in the sand-hill lakes. Knowledge of geographical distribution of the species is of importance. It does, however, in itself give little ecological information which is most needed in the management of aquatic wildlife.

ECOLOGICAL DISTRIBUTION OF THE SPECIES AND THEIR HABITATS

If a species is studied over the whole of its range, its ecological amplitude of adaptation to certain conditions of environment become known. Already in the early stages of collecting it became evident that the different species of Chara differed among themselves with regard to their habitat preferences and consequent distribution. There are not as yet enough ecological studies and collections available to draw final conclusions as to which species will grow best in a certain habitat, and what effect a certain species of Chara may exert on the aquatic community, or be influenced by it. Much more needs to be known about these plants to be of full aid to intelligent game management. To this end some observations are herewith presented.

CHARA CORONATA. Woods (11) states that this species is "common all over the state," but fails to support this statement by evidence. Nor do the eight herbarium records give much ecological information. In the experience of this writer, however, *Chara coronata* seems to have a definite habitat preference. Seven times out of eight, it occurred in intermittent pools of peculiar characteristics, formed in depressions on the table lands. The rhythmically submerged and emerged soils also are peculiar to these depressions and are known as Scott soils (8). These topographic depressions with their intermittent pools and peculiar aquatic plant communities, and whose soils are mapped as Scott soils, will henceforth be referred to as Scott bodies, to include in this term the whole of physiography, biology, soil and climate, to signify their unit character. The Scott bodies are the result of geologic and climatic processes, but are under control of climate. Late winter snows and spring rains supply water to these depressions, on the average from two to five feet deep. Summer showers tend to maintain the body of water, but increasing transpiration by plants and evaporating power of the air, with progressing season, lower the water level and dry up the pool, some as early as July and others as late as September. Many plants typical of the Scott bodies are annuals. They germinate, fulfill their seasonal life cycle, and produce seed before the soil becomes dry, and then pass the unfavorable period of the year in the seed stage. *Chara coronata* is an annual and was found to produce large quantities of spores before the time the pools dry up. These spores lying on the ground are subject to high temperatures and dryness, but apparently carry the plants successfully over to the next season. This species appears to be an important component of the aquatic communities of the Scott bodies, but more needs to be known about its biology and ecological distribution. *Chara coronata* seems however well adapted and in harmony with the peculiar environmental conditions of the intermittent pools of the Scott bodies of the table lands of Nebraska.

CHARA CONTRARIA. The earlier collectors contributed only six records from three counties for this species, and from this it might have been considered a rare inhabitant in Nebraska. The writer's collections, however, number fifty-five from eleven counties, although the majority came from only three counties and three habitats.

all of which were gravel pits. There are along the streams, and particularly along the Platte River, large numbers of pits, made by man to obtain sand and gravel. These pits fill up with ground water and as a rule have neither inlet nor outlet, but have usually a slow movement down grade as a part of the general ground water. Although there is an annual fluctuation in the water level, it does as a rule not exceed two to three feet. Most of the pits are deep, the greatest depth measured being sixteen feet. These bodies of water are referred to in this work as gravel-pit ponds, or ponds in short. There is always water in them. *Chara contraria* was found at depths that usually do not exceed five feet. Curiously, when this species is present in a pond, this is always clean, that is, the water is noticeably transparent, little plankton is in evidence, and blue-greens and blanket algae are nearly absent. Whether or not, Chara is a cause that cleans the water or keeps it clean, is not known to this writer at this time, but there are indications that it might be. Of many pits visited, the most recently created were devoid of Chara, suggesting that Chara is not a pioneer in the progressive development of the aquatic communities of these ponds. Of fifty-five collections of this species, fifty came from gravel-pit ponds, and the others from meander ponds of creeks, or intermittent marsh ponds. *Chara contraria* in Nebraska is therefore a characteristic species of the gravel-pit ponds. When the early collections of Chara were made in Nebraska, relatively few of the gravel pits had been in existence at that time, and the scant record of *Chara contraria* in the herbarium may be a good indication that this species developed in abundance only subsequent to the creation of these man-made ponds; it followed thus in the wake of the settlements by white man, finding greater opportunities to spread.

THE HAMILTON COUNTY CHARA POND. Located in the NW¼ sect. 6, T. 10 N., R. 8 W., 300 yards northeast and east from the bridge and highway crossing the Platte River from near Phillips to Grand Island, it is the largest pond of several, one being in the process of excavation at this time. Collections in this pond were made in July and August 1941, in July 1943, in February 1944, and observations in between and subsequent.

The plants of Chara cover perhaps sixty per cent of the bottom surface, and some grow three feet tall. There is a margin of shallow water where Chara does not grow. This suggests then that *Chara contraria* for optimum conditions of growth needs a certain depth of water to have these conditions fulfilled. One important factor may be temperature, as a deep body of water will not heat up as much as a shallow one, and temperature in turn may significantly affect carbon dioxide and oxygen pressures. Admixed with *Chara contraria* was *Chara fragilis* whose presence may indicate a more advanced stage of development of the aquatic community. The most luxurious growth with abundance of spore production was observed to occur during July. In the winter time the mats formed by the plants appeared more compact. Perhaps the stems were less buoyant, but more likely they were "grazed" by waterfowl and fish. Fish, frog, and smaller animal life were found hiding in the shelter of these mats. The immediate shore of this pond was devoid of willows, and there was very little amphibious shore vegetation, the soil being of coarse sand supporting only a xeric weed population.

THE DAWSON COUNTY GRAVEL-PIT POND. This pond is located at the northwest edge of the city of Lexington and apparently within the corporate city limits. It is administered by the park department of the city and has had some improvements around the pond, which, however, at the present time appear neglected. When first visited on Sept. 2, 1943, the shallower eastern part of the pond was uniformly covered with a dense mat of *Chara contraria*. A large quantity of these plants was taken out the same day and transported to Johnson Reservoir for the purpose of propagation in that reservoir lake. Among the stems of this transplant was a conspicuously large number of small crayfishes and other aquatic biota which in this way were also transplanted into the large reservoir. But a month and a half later, on Oct. 14, the Chara vegetation appeared considerably different. The mats appeared more compact, as though the tips of the stems had been "grazed" off, or had become lax and decumbent, or broken off. But outside the general mat there was a new growth of plants which had the appearance of being a different species. These were, however, young plants of the same species which had germinated from spores late in summer. Many plantlets were collected with the spore cases still attached to the young stems. These young plants did not survive during the winter. They were apparently too far out, in too shallow water where environmental conditions were not suitable for survival. In June 1944 the mats of *Chara contraria* showed luxurious growth where the water was three to four feet deep. The top of the mat had a distinct brownish appearance due to a preponderance of orange-colored antheridia. It is obvious that this species, as far as observed, has perennial stems, produces spores early in summer, with the maximum antheridial stage in the middle of June, shortly followed by the oogonial stage, which is followed by a physiological relapse in late summer when the spores already begin to germinate. Survival of young and old stems is assured in suitable environment during winter if not "grazed" by animals, or broken off by wave and ice action. The plants apparently are dormant during winter but again increase physiological activity and reproduction in spring and early summer. With a complete life cycle and local abundance in numbers the species seems to be in harmony with its climatic and physical environment.

THE KEITH COUNTY GRAVEL-PIT PONDS. There is a typical gravel-pit pond at the east edge of the town of Ogallala which is inhabited by *Chara contraria*. There are many small ponds just below Kingsley dam on the North Platte River, about eight miles northeast of Ogallala. Many of these ponds are also inhabited by *Chara contraria* which grows here in a similar way and under similar conditions as in the ponds reported above. With eight collections of *Chara contraria* in these ponds was found once each *C. fragilis* and *C. foetida*.

CHARA FRAGILIS. Sixteen collections of this species from four counties were made by this writer. Four collections came out of the pond in Hamilton county where it grew as a subdominant with *Chara contraria*. One sparse collection came out of another pit across the Platte River from Hall county. Seven collections came from Keith county. Only two came from gravel-pit ponds at Kingsley dam. All these collections so far enumerated for this species came from typical gravel-pit ponds where *Chara contraria* was the dominant member of this family. The next collection from Keith county came from a floodplain pond west of Keystone at the southern edge of the sandhill area. This pond was a shallow depression in a marsh mostly supplied by ground water, and surrounded by wet meadow, therefore, a marsh pond. Here *Chara fragilis* was the dominant, although *Chara contraria* was well represented. Four collections came from the sand hills about nine miles north of Kingsley dam from the east side of highway 61 in sect. 18, T. 16 N., R. 38 W. This is a low area with the water table close to the surface supplying the several small ponds with most of the water. The ponds might have been made by the road builders to obtain gravel, but their characteristics are more those of marsh ponds. The dominant was again *Chara fragilis* with an admixture of *Chara contraria*. Four collections were made in Arthur county, a typical sand-hill county. One collection was made on the east side of highway 61, three miles south of the town of Arthur, from a dried-up pond in a similar marshy situation as the last mentioned from Keith county. There too, *Chara fragilis* was the dominant with *Chara contraria* admixed. The other three collections came from Beeken Lake, a typical shallow sand-hill lake, surrounded by marshes and wet meadows. The only species of this family present was *Chara fragilis.* The records in the herbarium number twelve and from their scanty information it may be surmised that most of them also came from sand-hill lakes and marsh ponds. It is then in the sand-hill lakes and marsh ponds that *Chara fragilis* is best at home in Nebraska, and wins in competition over the other species of Chara.

CHARA FOETIDA. Only one collection of this species was made by this writer. It came out of the gravel-pit ponds at Kingsley dam where it grew with *Chara contraria.*. This is too scant to reach any conclusions regarding the ecological distribution of the species.

RARE SPECIES. Seven species, *Chara aspera, C. evoluta, C. sejuncta* and *C. verrucosa, Nitella acuminata* var. *subglomerata, N. axillaris* and *N. opaca,* were nearly all collected by the earliest collectors in single collections. Three single collections of *Chara gymnopus, Nitella batrachosperma,* and *N. clavata* were made by the writer and are additions to the flora of this family for this state. There are thus ten species of this family found so sparingly that very little can be inferred from their presence.

AGENTS OF DISTRIBUTION

The question arises how do the species of Characeae become scattered over such wide areas. As the plants are non-motile, anchored to the bottoms of pools and ponds, and sink to the bottom when broken off because of their incrustation with lime, they must have effective and unceasing agents which carry on the dispersal of their propagules. These agents are obviously the aquatic birds, mainly ducks. Although there is no direct information available, it is not difficult to imagine that parts of the brittle stems, with or without adherent spores, might cling to the feathers or feet of the birds. A little mud with it might help in carrying such plant parts over relatively long distances. Some spores may pass the intestinal tracts of the birds and remain viable.

It is generally estimated that ducks by the millions cross Nebraska twice annually during their migrations. As they fly from pond to pond there are therefore twice a million chances to carry propagules from one place to another over wide areas. Some of these surely must find a suitable place to propagate and become established. If the lakes of the sand hills are the most suitable places for *Chara fragilis,* it would be expected that this species also would be carried to the ponds of the gravel pits in the adjacent Platte Valley, where they would be able to grow and compete with other plants on a reduced scale only, due to the dissimilarity of the two environments. Similar dispersal takes place among the other species and their respective habitats. The rarer species of Chara, and particularly those of Nitella, seem to indicate this condition of dispersal. Since out of 141 collections only six were of Nitella, it must be presumed that the environmental conditions in Nebraska are not suitable for the requirement of these species, hence, they do not survive. Dispersal, however, takes place continually and some plants may succeed for a season or two. *Nitella batrachosperma* and *N. clavata* were collected in 1941 on the Scott body on the highway one mile east of Grant in Perkins county. By the summer of 1943 this whole aquatic community was destroyed, partly by drought and partly by hogs. *Nitella opaca* was collected in 1890 in considerable quantity at Lincoln in a creek known as Deadman's Run. None are to be found there to-day, none would be expected because the creek has been channeled and is now mostly dry. Man's work has here eradicated the habitat of one species, but in the case of the gravel-pit ponds he has created many more new habitats into which the ducks carry unwittingly the propagules for the perpetuation of their own food.

GEOLOGICAL OCCURRENCE OF CHARA

One might also wonder how long the species of Characeae have been inhabitants of the area known as Nebraska. That the plants are so widely distributed over the state seems to indicate that they must have been age-long components of the aquatic communities in this state. So far as this writer is aware Chara has never been reported for certain in the fossil state from the rock beds of Nebraska. It was the good fortune of this writer in 1943 to run on to a small deposit of fossilized Chara in a rock on the shore of Kingsley lake. The fossils were embedded in a buff-colored, hard marl, of the Ash Hollow formation, Ogallala Group of Pliocene age (3). The locality of this find is in the north-facing bluffs, on the shore of Kingsley lake, about six miles north of Ogallala and half a mile east, in the N½ sect. 5, T. 14 N., R. 38 W. A detailed study of the plant fossils has not yet been made, but it is believed that they are rather widespread in this rock formation, but have thus far escaped recognition. Members of the family Characeae have therefore a long history in Nebraska and may originally have been brought here by the ducks or other waterfowl.

CHARA IN RELATION TO AQUATIC WILDLIFE MANAGEMENT

Martin and Uhler (5) in an important treatise of foods for game ducks, list from stomach analysis Chara as fifth in importance for the United States and Canada. They list it as fourth in rank for the western region of the United States. They list its food value as good to excellent and give some detailed information. Though Chara is of great importance as direct food to waterfowl, it may have a yet greater importance in its community relations and as nurse bed for large quantities of small animal life, which is very important food to fish. As pointed out above, Chara is usually found only in clean ponds, but it is not known whether this is a cause or a result.. Two ponds were puzzling, one in Hall County southeast of Grand Island, in the apex of a triangle formed by highway 2 and the Platte River in the SE¼ sect. 35, T. 11 N., R. 9 W., and the other in Buffalo County, south of Kearney in the very corner formed by highway 10 and the Platte River in the SW¼ sect. 13, T. 8 N., R. 16 W. Both of these ponds were visited in July 1941 and had at this time overwhelming masses of algae, chiefly *Rhizoclonium hieroglyphicum,* much of which was in a state of decay and gave off bad odors, giving the ponds generally an ugly appearance. No Chara was in evidence. But in 1943 when the same ponds were again visited they had a much cleaner appearance and the blanket algae were present only in much reduced quantities. *Chara contraria* was now present in both ponds and in addition *Chara fragilis* in the Hall County pond. By June 1944 both ponds looked even fresher and cleaner with fewer algae than before. Perhaps there is a normal sequence in which Chara can only develop after some organic matter has been deposited in the pond, or else there is a possibility that Chara might give off some substance toxic to other algae and prevent them from growing in their proximity. Whatever the real reason or true sequence in the population cycles of these ponds, game management will need to know the exact facts.

On the other hand the whole economy of raising fish in the state hatchery on Rock Creek in Dundy County seems to be based chiefly on *Chara contraria.* When the ponds had been dug out to hold the fish, Chara appeared naturally and became a dominant plant. Now every year at the end of the season the plants of *Chara* have to be removed from the ponds to make seining of the fish possible. Tons of Chara are removed from the water and thrown upon the banks and later hauled away. The cleaning-out of these plants is undertaken only to make the seining possible, hence much of the plant material, such as spores, remain to provide a new crop for the following year. Inseparably connected with the plants are the quantities of animal life which represent the food needed to raise the fish. While many plants enter into this economy, it seems certain that *Chara contraria* is the most important, perhaps the basic one in the whole food chain of raising fish successfully.

Over the ridge where the tons of Chara have been dumped over the years a small white hill has been formed by the lime incrusted plants. The idea suggested itself that these tons of Chara taken out of the ponds annually, might represent not only propagating material to put in other newer ponds, but might be valuable as lime fertilizer on land gone sour. It certainly would contain quantities of finely divided lime with much nitrogenous matter of value to poor soils. Uses for this material may be found and Chara may become even more valuable as a natural resource.

SUMMARY

In 1894 was published the first paper on Characeae in Nebraska, based on twenty-five collections which already established the names of twelve species. The next thirty-eight years added thirty-three, mostly unidentified collections to the herbarium. From 1941 to 1944 the writer added eighty-three records making the total on which this paper is based 141 records. Ecological information has now been added which shows tendencies for *Chara coronata* to occur mainly in the intermittent pools of the table lands, for *C. contraria* to be at home in the gravel-pit ponds made by man, and for *C. fragilis* and *C. foetida* to occupy the lakes in the sand hills. Fossilized plants found in the Ash Hollow formation of Pliocene age indicate that this family was represented in this area in geological time. Waterfowl are the agents of geographical dispersal of the Characeae. Some species of Chara are important food to waterfowl, chiefly some ducks. The mats of

Chara are nurse beds for small aquatic animals and are generally important in the aquatic foodchain. It is suggested that Chara might be useful as a lime fertilizer on poor land. New names to the state flora are, *Nitella batrachosperma, N. clavata,* and *Chara gymnopus.*

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TABLE I.

Geographical Distribution of Characeae by Counties

Counties	Species	Collections	
		Kiener	Herbarium
ARTHUR	C. contraria	1	
	C. fragilis	4	
BANNER	C. foetida		1
BOYD	C. contraria		1
	C. foetida		1
BROWN	C. fragilis		1
BUFFALO	C. contraria	2	
CASS	C. coronata		1
	C. foetida		1
CHASE	C. contraria	2	
CHERRY	C. aspera		1
	C. contraria		4
	C. coronata		5
	C. evoluta		2
	C. foetida		4
	C. fragilis		6
	C. verrucosa		2
DAWES	C. contraria		1
	C. foetida		5
	C. fragilis		1
DAWSON	C. contraria	11	
DODGE	C. gympnopus	1	
DUNDY	C. contraria	2	
	C. foetida		1
FILLMORE	C. coronata	3	
FRANKLIN	C. coronata	1	
GARDEN	C. contraria	2	
GRANT	C. fragilis		1
GREELEY	C. foetida		1
HALL	C. contraria	3	
	C. fragilis	1	
HAMILTON	C. contraria	13	
	C. coronata	1	
	C. fragilis	4	
HITCHCOCK	C. contraria	1	
HOLT	C. fragilis		1
KEARNEY	C. sejuncta		1
KEITH	C. contraria	17	
	C. coronata	1	
	C. foetida	1	
	C. fragilis	7	
KIMBALL	C. foetida		1

TABLE I—(Continued)

Geographical Distribution of Characeae by Counties

Counties	Species	Collections	
		Kiener	Herbarium
LANCASTER	N. a. subglomerata		1
	N. opaca		1
LINCOLN	C. contraria	1	
MERRICK	C. foetida		1
MORRILL	C. foetida		1
PERKINS	N. batrachosperma	1	
	C. coronata	1	
	N. clavata	1	
PHELPS	C. coronata	1	
SHERIDAN	C. evoluta		1
SIOUX	C. evoluta		1
	C. foetida		1
THOMAS	C. coronata		1
	C. foetida		1
	C. fragilis		1
WEBSTER	C. fragilis		1
YORK	N. a. subglomerata		2
	N. axillaris		1
	C. coronata		1

TABLE II

Geographical Distribution of Characeae by Species

Species	Counties	Collections	
		Kiener	Herbarium
N. a. subglomerata	LANCASTER		1
	YORK		2
N. axillaris	YORK		1
N. batrachosperma	PERKINS	1	
N. clavata	PERKINS	1	
N. opaca	LANCASTER		1
C. aspera	CHERRY		1
C. contraria	ARTHUR	1	
	BOYD		1
	BUFFALO	2	
	CHASE	3	
	CHERRY		4
	DAWES		1
	DAWSON	11	
(14 counties represented)	DUNDY	2	
	GARDEN	2	
	HALL	3	
	HAMILTON	13	

TABLE II—(Continued)

Geographical Distribution of Characeae by Species

Species	Counties	Collections Kiener	 Herbarium
	HITCHCOCK	1	
	KEITH	17	
	LINCOLN	1 (55)	(6)
C. coronata	CASS		1
	CHERRY		5
	FILLMORE	3	
	FRANKLIN	1	
	HAMILTON	1	
(10 counties represented)	KEITH	1	
	PERKINS	1	
	PHELPS	1	
	THOMAS		1
	YORK	(8)	1 (8)
C. evoluta	CHERRY		2
	SHERIDAN		1
	SIOUX		1
C. foetida	BANNER		1
	BOYD		1
	CASS		1
	CHERRY		4
	DAWES		5
	DUNDY		1
(13 counties represented)	GREELEY		1
	KEITH	1	
	KIMBALL		1
	MERRICK		1
	MORRILL		1
	SIOUX		1
	THOMAS	(1)	1 (19)
C. fragilis	ARTHUR	4	
	BROWN		1
	CHERRY		6
	DAWES		1
	GRANT		1
(11 counties represented)	HALL	1	
	HAMILTON	4	
	HOLT		1
	KEITH	7	
	THOMAS		1
	WEBSTER	(16)	1 (12)
C. gymnopus	DODGE	1	
C. sejuncta	KEARNEY		1
C. verrucosa	CHERRY		2

THE CHARACEAE OF NEBRASKA

By Fay Kenoyer Daily

Early in 1943 during the course of correspondence between W. A. Daily and Dr. Walter Kiener, it was arranged for some of the Nebraska Characeae to be sent to the author for study and identification. This taxonomic work was in conjunction with a geographical and ecological consideration of the family in Nebraska in which Dr. Kiener was interested at that time. Later that year, when he had an opportunity for an extended collecting trip for the Game and Fish Commission, Dr. Kiener conceived the idea for the related studies presented in this issue. Toward this end, specimens found at the University of Nebraska were made available and subsequent collections by Dr. Kiener were supplied for study. The object of this resulting paper is to review the Characeae already published for the state and to report additional collections. To aid other students in identification of this group a key, descriptions and illustrations are given.

A complete representation of specimens cited in this study may be found in the herbarium of the University of Nebraska, and an almost complete set may be found in the personal herbarium of the author at Butler University. Duplicate sets of the specimens collected by Dr. Kiener are now being distributed.

Terminology used is the same as that published in a convenient glossary by Groves and Bullock-Webster (15).

Five species of Nitella and nine species of Chara are included in this paper. Two species of Nitella formerly reported for Nebraska by Woods (23) and Webber (22), viz. *Nitella flexilis* Ag. and *Nitella mucronata* A. Br., are not included because specimens were not found to support these reports. *Nitella translucens* forma *confervoides* Thuill. reported by Woods (23), and possibly the same specimen reported by the Nebraska Botanical Survey III (13), is also not included because it was not found in the specimen indicated.

The author is indebted to Dr. Walter Kiener of the Conservation and Survey Division of Nebraska for suggesting this work and aiding in assembling plants and literature for study; to the University of Nebraska for the loan of specimens; to Dr. Ray C. Friesner of

Butler University for making available the facilities of the Butler University Botany Department and for making helpful suggestions; to Dr. C. M. Palmer and Dr. J. E. Potzger of Butler University for offering encouragement and advice; to Dr. Francis Drouet of the Chicago Natural History Museum for making available the facilities of the cryptogamic herbarium of the museum and for constructive criticism; and to W. A. Daily of the Butler University Herbarium for helpful suggestions.

KEY TO THE CHARACEAE OF NEBRASKA

Coronula composed of two superimposed rows of five cells each. Antheridia terminal .... NITELLA

Ultimate rays of branchlets one-celled. Coronula deciduous.

Monoecious.

Heterophyllous (branchlets of two sorts; accessory, simple branchlets produced below and alternately with once-furcate branchlets .... 1. *Nitella clavata*

Homoeophyllous (branchlets similar, once-furcate) .... 2. *N. subglomerata*

Dioecious; branchlets simple, once-furcate .... 3. *N. opaca*

Ultimate rays of branchlets all two-celled, one-half total length of branchlet. Coronula persistent .... 4. *N. batrachosperma*

Ultimate rays of branchlets two to three-celled, length insignificant as compared with total branchlet, especially in sterile branchlets. Coronula persistent .... 5. *N. axillaris*

Coronula composed of one row of five cells. Antheridia produced below oogonia in monoecious species .... CHARA

Ecorticate; stem and branchlets naked .... 6. *Chara coronata*

Corticated; stem and portions of branchlets covered by a sheath consisting of longitudinal rows of cells.

Stem falsely haplostichous; secondary cells developed, but extend only a very short distance from node .... 7. *C. evoluta*

Stem diplostichous; secondary cells sometimes overlap a short distance.

Primary cells prominent .... 8. *C. contraria*

Secondary cells prominent .... 9. *C. foetida*

Stem triplostichous, sometimes irregular.

Lowest branchlet internode diplostichous.

Monoecious.

Cells equal in diameter and rather regularly corticated .... 10. *C. fragilis*

Cells unequal in diameter; primary cells larger and more prominent, regularly triplostichous .... 11. *C. verrucosa*

Dioecious; cells about equal in diameter and prominence, irregularly triplostichous due to long overlapping secondary cell ends .... 12. *C. aspera*

Lowest branchlet internode ecorticate, next internode triplostichous, rarely all naked.

Antheridia and oogonia conjoined (borne at same node)..13. *C. gymnopus*

Antheridia and oogonia disjoined (borne at different nodes)..14. *C. sejuncta*

1. NITELLA CLAVATA (Bertero) A. Br., Char. Aust. Hook. Journ. 1: 195. 1849.

Plate I-A

Habit lax in lower portions, crowded in upper, about 10 cm. high; monoecious; branchlets heterophyllous, i. e. whorl is compound with once-divided branchlets occurring alternately with and directly above simple undivided ones; sometimes there is no simple branchlet found between divided branchlets, or, perhaps more than one can be found there; about six divided branchlets at node, each bearing 2-4 one-celled ultimate rays; ultimate rays inflated, sharply-pointed; simple branchlets also inflated and sharply-pointed in upper portions of plant, linear in lower portions; oogonia 1-3 at node of divided branchlets in upper portion of plant, coronulae short and not deciduous; oospores red brown, 0.27-0.32 mm. long, 0.27-0.32 mm. wide with 6-7 sharply flanged ridges; membrane red brown, surface minutely granulated, translucent; antheridia about 0.27 mm. in diameter. Specimens seen: PERKINS COUNTY: mud of intermittent pool east of Grant, *Walter Kiener 10779,* Aug. 4, 1941.

2. NITELLA SUBGLOMERATA A. Br. Characeen aus Colombia, Guyana und Mittelamerika. Monatsbericht Berlin Akad. p. 356. 1858. *Nitella acuminata var. subglomerata* A. Br. of later publ.

Plate I-B

Habit spreading and diffusely branched; plants about 20 cm. high; stem about 1.0 mm. wide, sterile branchlets slightly narrower; monoecious; sterile verticels somewhat exceeding fertile verticels, i. e. sterile branchlets are about 2-7 cm. long and overtop the fertile whorls which are about 3-5 mm. long and which are borne on peduncles of varying length located in the axils of the sterile whorls; branchlets similar; fertile branchlets 6-8 at node, once-divided into 2-4 one-celled terminal rays which gradually taper to a point and which are about one-third to one-half the total length of the branchlet; sterile branchlets 6-8 at node, once-divided into 2-3 one-celled terminal rays which gradually taper to a point and which are about one-third to one-half the total length of the branchlet; fructification not enveloped in jelly; oogonia 1-3 at a node; coronulae short, persistent; oospores with 6-7 ridges, 0.24-0.28 mm. long, about spherical, red-brown; membrane light brown, translucent, roughened with irregular granules which give the appearance of reticulation in mature oospores when a 15X ocular and 10X objective are used; in immature oospores, granules are scattered and even not seen in some cases; antheridia about 0.32 mm. in diameter.

No specimens were seen to support the following report: Woods (23), "*Nitella subglomerata* A. Br.—Minden."

Specimens seen: LANCASTER COUNTY: pond south of penitentiary near Lincoln, collector unknown, July 30, 1891 (probably the basis of Webber's (22) report, "*N. acuminata* A. Br. var. *glomerata* A. Br. Ponds near Lincoln (Bessey)." YORK COUNTY: with *C. coronata* Ziz., *May Hopper 625,* June, 1891; York, *May Hopper,* 1893 (probably the basis of Woods' (23) report, "*Nitella subglomerata* A. Br.—York.")

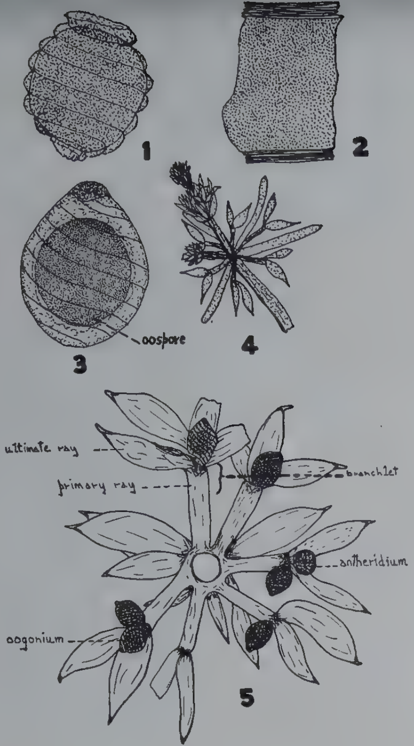
3. NITELLA OPACA Ag. Syst. Alg. p 124. 1824.

Plate I-C

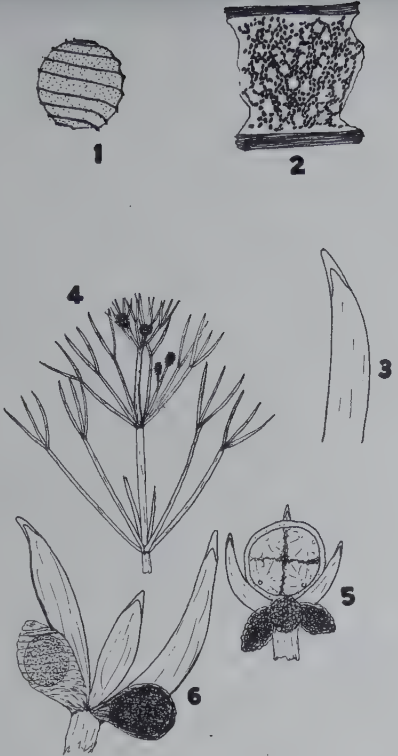
Habit elongate and lax, not greatly branched, stem internodes usually two to four times length of branchlets; dried plants dark green and opaque; dioecious; stem about 0.8 mm. wide; fertile verticels usually contracted into dense heads but sometimes lax; sterile verticels elongate, spreading; branchlets of fertile verticels up to 4-5 mm. long, once-furcate into 2-3 one-celled, rather blunt ultimate rays with mucronate tips; branchlets in sterile whorls 6-7, up to about 3-4 cm. long, variable in length, simple or once-furcate into 2-3 one-celled bluntish ultimate rays with mucronate tips; fertile verticels not enveloped in jelly; no mature oogonia seen in material examined, but Braun (14) reported, "Nord-Amerika.—Sporangienkern 0.36-42 mm. lang, 0.32-35 mm. dick." (Braun used this method to indicate 0.36-0.42 mm. etc.); antheridia up to 0.74 mm. in diameter—still probably not mature.

Included here is the specimen reported by Woods (23), "*Nitella opaca* Ag.—Deadman's Run, Lincoln."

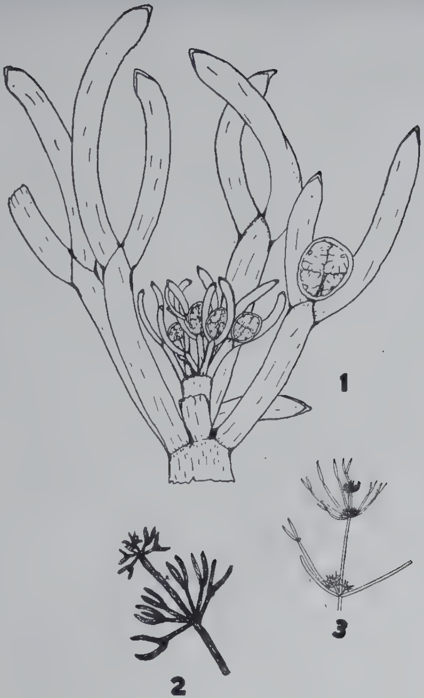
Specimens seen: LANCASTER COUNTY: Deadman's Run, Lincoln, *H. J. Webber 7430, 7431,* May, 1890, and *6093,* May 1890. (It is uncertain whether the following citation refers to any of these specimens:



I-A



I-B



1-C

I-A. Nitella clavata A. Br. 1. Oospore. 2. Portion of the membrane of the oospore. 3. Oogonium. 4. Portion of plant, natural size. 5. Fertile verticel seen from above.

I-B. Nitella subglomerata A. Br. 1. Oospore. 2. Portion of the membrane of the oospore. 3. Apex of branchlet. 4. Portion of the plant, natural size. 5. Portion of young fertile branchlet. 6. Portion of the older fertile branchlet.

I-C. Nitella opaca Ag. 1. Tip of male plant enlarged. 2. Portion of male plant, natural size. 3. Portion of female plant, one-half natural size (reproduced from Woods, 23, Pl. XXVII).

Bessey and Webber (12), "*Nitella opaca* Ag. 834½. In small, stagnant pond, Lincoln, May 5, 1890. A medium sized dioecious species found in considerable quantity by Mr. Shimek, of the State University.")

4. NITELLA BATRACHOSPERMA A. Br. in N. Denks. Schweiz. Ges. Naturw. 10:10. 1847. (nomen.); in Cohn's Krypt. Fl. Schles., p. 400. 1876. non Agardh.

Plate II-A.

Habit similar to *N. tenuissima,* small and delicate, stem internodes 1-3 times length of branchlets; monoecious; branchlets similar, 8 in whorl, about 1.0-1.5 mm. long, 1-2 furcations with secondary rays about 4 and ultimate rays about 4; ultimate ray about one-half length of whole branchlet, uniformly two-celled ending in slender sharply-pointed mucro; fertile verticel not enveloped in jelly (some forms may be enveloped according to the literature); oogonia borne singly at the first and sometimes the second furcation; coronulae small, persistent; oospores bear 6-7 flanged ridges, about 0.19 mm. long and about as broad, dark brown; membrane showing interrupted reticulation, translucent, pliable; no mature antheridia seen.

Specimen seen: PERKINS COUNTY: bottom of intermittent pool east of Grant, *Walter Kiener 10641a,* Aug. 1, 1941.

5. NITELLA AXILLARIS A. Br. Monatsber. der Berl. Akad., p. 356. 1858.

Plate II-B.

Habit slender, not greatly branched, bearing about 8 branchlets at a node; sterile branchlets long, spreading; fertile verticels contracted into axillary heads; monoecious; fertile branchlets with about 2-3 furcations, primary ray 0.11 mm. by 0.42 mm., at first furcation 4 secondary rays 0.08 mm. by 0.32 mm., at second furcation 3-4 ultimate rays or tertiary rays as the case may be 0.05 by 0.1-0.53 mm.; if divided again, usually 3-4 ultimate rays about the same size as the tertiary rays; ultimate ray two-celled ending in mucro 0.02-0.025 mm. in width at base by 0.05-0.1 mm. long; sterile branchlets once-furcate ending in crown of 4 minute 2-celled rays 0.04 mm. wide by 0.1 mm. long or shorter; oogonia aggregated at either first or second node; coronulae rather long, persistent; oospores have 5-7 ridges, 0.27 mm. by 0.24 mm., light brown; membrane bears 4-5 reticulations to each 0.027 mm., light brown, translucent; antheridia about 0.3 mm. in diameter.

Included here is the specimen reported by Woods (23) as *Nitella translucens* Pears. and Nebraska Botanical Survey Report for 1893 (13) as the same.

Specimen seen: YORK COUNTY: with *Chara coronata* Ziz., *May Hopper 625,* June, 1891.

6. CHARA CORONATA Ziz. A. Br. Ann. d. sc. Nat. Series 2, 1: 353. 1834; Flora 18 (1): 59. 1835.

Plate II-C.

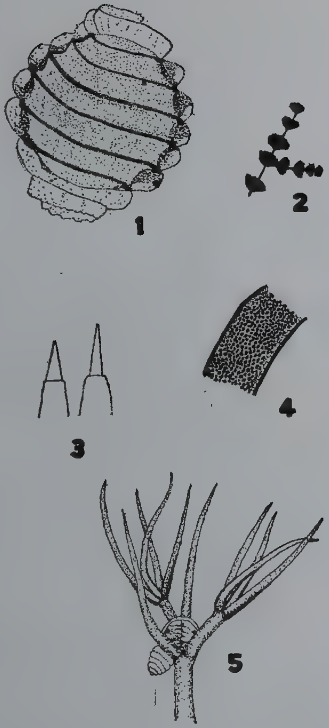
Habit sometimes tufted, stem and branchlets entirely uncorticated and usually unincrusted, so generally not rigid, often frequently branched; 8-10 branchlets bearing a variable number of segments tipped by a crown of short bract cells surrounding an equally short terminal cell; monoecious; stipulodes in one series alternate with the branchlets and varying greatly in size; bracteoles slightly shorter to a little longer than oogonia, variable; posterior bract cells developed or entirely lacking, variable; oospores with 7-9 ridges, 0.43-0.58 mm. long, dark brown to black; membrane dark brown to light brown, granular; antheridia found up to 0.4 mm. in diameter.

Included here are the specimens reported by Smith and Pound (21), *"Chara coronata* A. Br. In small lake, Cherry county, July 18. (265)."; Woods (23), *"Chara coronata* Ziz. The specimens in the herbarium of the Botanical Survey from Cherry county and from Greenwood . . .".

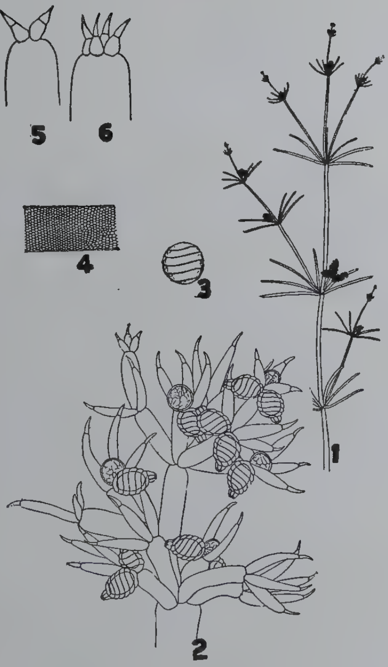
No specimens were seen to support the following reports: Bessey and Webber (12), ". . . Belmont; Ft. Robinson, July 29."; Pound and Clements (19), *"C coronata* . . . pools and small lakes in the wet valleys of the Loup district."

Some authors have divided *Chara coronata* Ziz. into subspecies *Chara braunii* Gmelin and *Chara Schweinitizii* A. Br. representatives of which might be recognized in specimens from Nebraska. Confusing intermediates occur, however, so the present paper only points these out as the extremes of *Chara coronata* Ziz. that may be found.

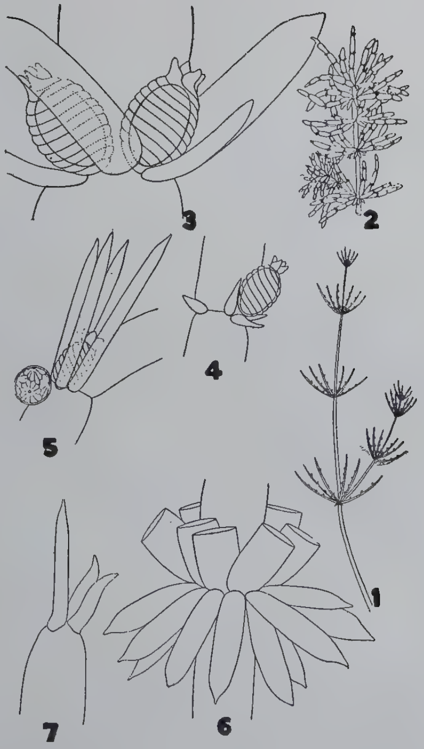
Robinson (20) who cites illustrations found in Woods (23) Pl. 30, figs. 1, 4 and Pl. 30, figs. 2, 3, 5-7 respectively gives these a tentative differentiation as follows:



II-A



II-B



II-C

II-A. Nitella batrachosperma (Reich.) A. Br. 1. Oospore. 2. Portion of plant, natural size. 3. Tips of two branchlets showing mucro on each. 4. Portion of membrane of oospore. 5. Fertile branchlet.

II-B. Nitella axillaris A. Br. (Rearranged and reproduced from Woods, 23, Pl. XXIX, Nitella translucens.) 1. Portion of plant, one-half natural size. 2. Fertile verticel. 3. Oospore. 4. Portion of the membrane of the oospore. 5, 6. Tips of sterile branchlets.

II-C. Chara coronata Ziz. (Rearranged and reproduced from Woods, 23, Pl. XXV.) 1. Portion of plant, one-half natural size. 2. Portion of plant, one-half natural size. 3, 4, 5. Fertile branchlet nodes. 6. Stem with bases of branchlets

"Bracteoles shorter than the mature sporocarp; posterior leaflets nearly always wanting. (In key.)

Stipulodes—0.4-0.8 mm. long and 0.17-0.21 mm. wide (In text.)

C. Braunii Gmelin
Plate II-C, figs. 1,4.

Bracteoles at least as long as the mature sporocarps (In key.)

Stipulodes—usually 1.5-3.5 mm. long and 0.56-1.5 mm. wide (In text.)

C. Schweinitzii A. Br."
Plate II-C, figs. 2, 3, 5, 7.

Specimens seen: CASS COUNTY: in ponds at Greenwood, *J. G. Smith,* July 2, 1890. CHERRY COUNTY: *J. G. Smith* and *Roscoe Pound 265,* July 18, 1892; with *Chara fragilis* Desv., *J. G. Smith* and *Roscoe Pound 262,* July 19, 1892; at Simean, *John M. Bates,* July 21, 1892; Wood Lake, *John M. Bates,* Aug. 13, 1898; with *Chara fragilis* Desv., Hackberry lake, *Palmatier* and *Porter,* June 11, 1936. FILLMORE COUNTY: soil of intermittent pool west of Fairmont, *Walter Kiener 10401*, July 21, 1941; wet soil of intermittent pool at Shickley, *Walter Kiener 11056,* Aug. 14, 1941. FRANKLIN COUNTY: shallow water of intermittent pool south of Macon, *Walter Kiener 11044,* Aug. 13, 1941. HAMILTON COUNTY: on bottom of intermittent pool southwest of Aurora, *Walter Kiener 10415,* July 21, 1941. KEITH COUNTY: with *Chara contraria* A. Br., pools on Whitetail creek near Keystone, *Walter Kiener 15607,* Sept. 20, 1943. PERKINS COUNTY: bottom of intermittent pool east of Grant, *Walter Kiener 10641,* Aug. 1, 1941. PHELPS COUNTY: submerged on bottom of intermittent pool near Loomis, *Walter Kiener 10446,* July 23, 1941. THOMAS COUNTY: stagnant ponds at Thedford, *H. J. Webber 6524* (*No. 5*), July 14, 1889 (this may be the specimen referred to by Bessey and Webber, 12, "833. *Chara coronata* A. Br. Very common in the ponds of central and western Nebraska. Thedford, July 10." Collection date is different however). YORK COUNTY: *May Hopper 625,* June, 1891 (probably the basis of Woods', 23 report, "*Chara coronata* Ziz. The specimens collected at York 1893 by Miss Hopper . . .").

7. CHARA EVOLUTA Allen. Bull. Torrey Bot. Club 9: 41. pl. 19. 1882.

Plate III-A.

Habit short, much branched, very spinose; monoecious; stem falsely haplostichous having secondary cells developed but usually only extended a very short distance either side of the node; spine cells single to three together usually two together—one short and one long, may be two long ones together; stipulodes in two series, well developed, variable; lowest branchlet internode haplostichous; tip of branchlet made up of a short uncorticated cell surrounded by a tuft of bract cells; bracteoles long up to about twice length of oogonium; posterior bract cells slightly shorter; oospore with 10-12 inconspicuous ridges, about 0.58 mm. long, dark brown to black; membrane light to dark brown, granular; antheridia 0.27-0.37 mm. in diameter.

Included here are specimens reported by: Woods (23) as *"Chara evoluta* Allen. In a lake, Sheridan county, Smith and Pound No. 264."; Smith and Pound (21), *"Chara foetida* A. Br. var. *longibracteata* A. Br. Ponds in wet valleys, Sheridan county, July 12, 13. (264)"; Bot. Surv. of Neb. III (13), *"Chara evoluta* Allen. Sheridan county, part of material reported as *C. foetida longibracteata* in 1892 Report. (265½)"; Anderson and Walker (10), "Phalaris lake—*C. evoluta*."

Robinson (20) cited illustration by Woods (23) Pl. 34.

Specimens seen: CHERRY COUNTY: with *Chara contraria* A. Br., *J. G. Smith* and *Roscoe Pound 263,* July 15, 1892; "Phalaris" lake, *Elda R. Walker* 38, July 1912. SHERIDAN COUNTY: lake, *J. G. Smith* and *Roscoe Pound 264,* July 19, 1892. SIOUX COUNTY: with *Chara foetida* A. Br., Pine Ridge, *Webber,* June 29, 1889.

8. CHARA CONTRARIA A. Br. Übersicht der Schweizerischen Characeen (neue Denkschriften d. allegemeinen schweizerischen Gesellschaft für die gesammten Naturwissenschaften 10. 1849). Kutz. Phyc. Germ. p. 258. 1845.

Plate III-B

Habit variable, not greatly branched, at times loose and rough in appearance similar to *Chara foetida,* but usually more rigid; monoecious; stem diplostichous, primary cells prominent (sometimes cells almost equal), sometimes regular, but more often irregular with secondary cell ends slipping past one another a considerable distance or with secondary cells developed from both sides of a node but one developed only in one direction; spine cells variable, usually short spines in younger portions of stems, in older portions usually deciduous, in some varieties may develop to considerable length, however; stipulodes in two series, usually short, blunt, deciduous in many cases leaving only scars; lowest internode of branchlet diplostichous; tip of branchlet with 1-5 ecorticate cells, end cell usually the shortest; bracteoles variable, from shorter than to 6-7 times as long as oogonia;

posterior bract cells usually papilliform but sometimes developed to as long as 5 times their breadth; coronulae of oogonia usually short and connivent; oospores bearing 9-14 ridges, sometimes extending downward to form basal claws or cage, 0.48-0.74 mm. long, dark brown to black; antheridia up to 0.58 mm. in diameter when mature.

Included here are the specimens reported by Smith and Pound (21) as *Chara contraria* A. Br. "Ponds in wet valleys, Cherry county, July 17, 18. (263)"; Woods (23), as *Chara contraria* A. Br. "Ponca river, Boyd county."

No specimens were seen to support the reports of Anderson and Walker (10) for *Chara contraria* in Hackberry lake, in Watts lake and in Phalaris lake; Webber (22), "149. *C. contraria* A. Br. Flowing or standing water and cold springy lakes. Fremont. July (Williams)"; Woods (23), as *Chara contraria* A. Br. "Fremont"; Pound and Clements (19), "pools and small lakes in the wet valleys of the Loup district."

Robinson (20) cites illustration by Woods (23) Pl. 31.

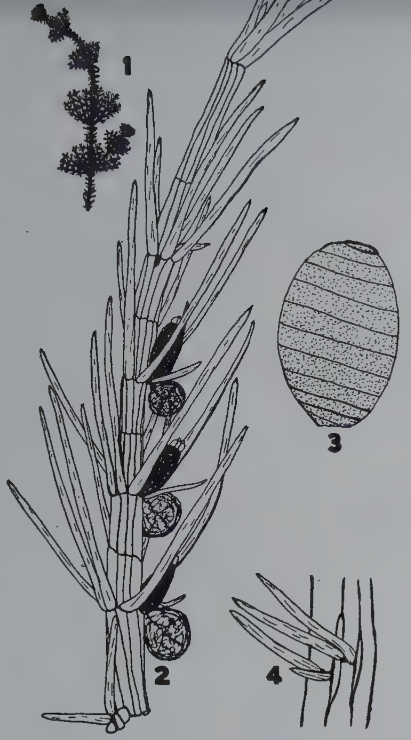
Specimens seen: (Specimens labeled here and elsewhere in this paper as "probable" are so mentioned since complete observations were not possible due to the state of preservation of the material, but enough characteristics were seen to be reasonably sure of identification.) ARTHUR COUNTY: probably *Chara contraria* A. Br. with *C. fragilis* Desv., in intermittent sandhill pool, 3 mi. south of Arthur, *Walter Kiener 15444,* Sept. 10, 1943. BOYD COUNTY: Ponca river, *Clements,* 1893. BUFFALO COUNTY: gravel pit pond south of Kearney, *Walter Kiener 15181,* Sept. 1, 1943. CHASE COUNTY: probably *C. contraria* in shallow water of swamp, Spring creek valley, *Walter Kiener 10753,* Aug. 3, 1941; mud of intermittent pool, Imperial, 5 mi. north, *Walter Kiener 10807,* Aug. 6, 1941. CHERRY COUNTY: *J. G. Smith* and *Roscoe Pound 263,* July 15, 1892 (probably the basis of Wood's, 23 report of *Chara contraria* A. Br. from ponds in Cherry county); Watts lake, *J. M. Bates 10,* 1894; Wood Lake, *J. M. Bates 655,* July 30, 1897; Hackberry lake, *Palmatier* and *Porter,* June 11, 1936. DAWES COUNTY: Crawford, *J. M. Bates 659,* July 13, 1897; at Wood Lake, Crawford, *J. M. Bates 7279,* date (?). DAWSON COUNTY: gravel pit pond at Lexington, *Walter Kiener 15218,* Sept. 2, 1943; probably *C. contraria* A. Br. in gravel pit pond at Lexington, *Walter Kiener 15985, 15986, 15987, 15988, 15989, 15990, 15996,* Oct. 14, 1943; in gravel pit pond at Lexington, *Walter Kiener 15991,* Oct. 14, 1943; probably *C. contraria* A. Br. in sandpit lake at

Lexington, *Walter Kiener 15997,* Oct. 14, 1943. DUNDY COUNTY: on mud in shallow creek, Rock Creek recreation grounds, *Walter Kiener 10538a,* July 26, 1941. GARDEN COUNTY: probably *C. contraria* A. Br. in North Platte river pool south of Oshkosh, *Walter Kiener 16243* and *16244,* Nov. 6, 1943. HALL COUNTY: gravel pit pond near Grand Island, *Walter Kiener 15158* and *15160,* Aug. 28, 1943; probably *C. contraria* A. Br. in gravel pit near Grand Island, *Walter Kiener 16397,* Feb. 4, 1944. HAMILTON COUNTY: on shallow bottom of pond, Platte river near Phillips, *Walter Kiener 10422,* July 22, 1941; submerged in pond, Platte river near Phillips, *Walter Kiener 11123,* Aug. 19, 1941; with *C. fragilis* Desv. submerged in sandpit lake, Platte river near Phillips, *Walter Kiener 14852* (in portion preserved in formalin), *14857,* July 30, 1943; submerged in sandpit lake, Platte river near Phillips, *Walter Kiener 14853, 14854, 14854a, 14854b, 14854c, 14855, 14856,* July 30, 1943; probably *C. contraria* A. Br. in gravel pit west of Phillips on Platte river, *Walter Kiener 16408, 16409, 16410,* Feb. 4, 1944. HITCHCOCK COUNTY: shallow water of intermittent pool, Stratton, Republican river pools, *Walter Kiener 10911,* Aug. 8, 1941. KEITH COUNTY: shallow water of intermittent pool at Ogalalla, South Platte river, *Walter Kiener 10683,* Aug. 1, 1941; gravel pit pond at Ogalalla, *Walter Kiener 15345,* Sept. 7, 1943; gravel pit pond at Kingsley Dam, *Walter Kiener 15488, 15493, 15496,* Sept. 13, 1943; gravel pit pond at Kingsley Dam, *Walter Kiener 15526, 15539, 15540, 15541, 15542,* Sept. 14, 1943; pools on Whitetail creek near Keystone, *Walter Kiener 15607* and *15607a* Sept. 20, 1943; with *C. fragilis* Desv. in dried-up pool west of Keystone, *Walter Kiener 15704,* Sept. 24, 1943; with *C. fragilis* Desv. in sandhill pond, Kingsley Dam, 9 mi. north, *Walter Kiener 16080, 16081,* Oct. 27, 1943; probably *C. contraria* A. Br. with *C. fragilis* Desv. in sandhill pond, Kingsley Dam, 9 mi. north, *Walter Kiener 16082,* Oct. 27, 1943. LINCOLN COUNTY: creek on flood plain, Platte river near Sutherland, *Walter Kiener 14899,* Aug. 1, 1943.

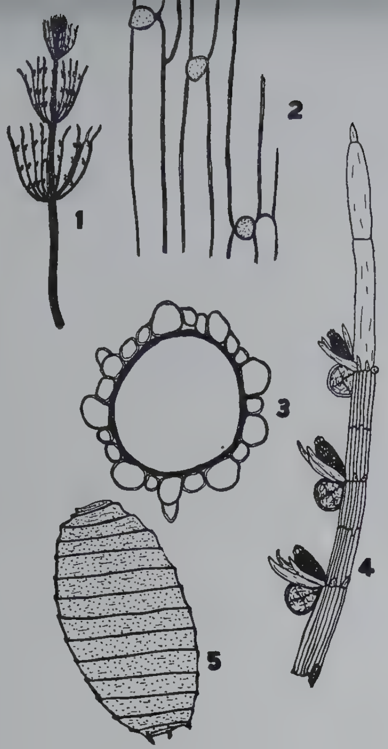
9. CHARA FOETIDA A. Br. Ann. Sci. Nat. ser. 2, 1: 354. 1834. *Chara vulgaris* L. Sp. Pl. 1156. 1753.

Plate III-C and IV-A.

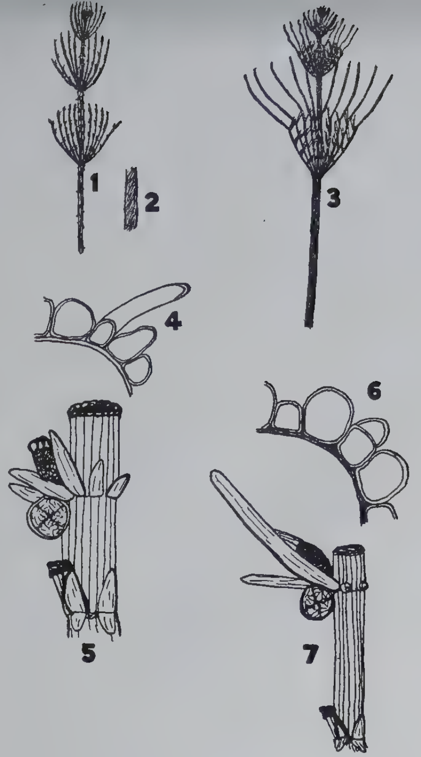
Habit spreading; stem moderately stout, branchlets 6-11 in a whorl; monoecious; stem diplostichous, secondary cells prominent, sometimes irregular; spine cells variable, usually papilliform or short, but in some varieties quite long; stipulodes in two series usually



III-A



III-B



III-C

III-A. Chara evoluta Allen. 1. Portion of plant, natural size. 2. Fertile branchlet with stipulodes at its base. 3. Oospore. 4. Portion of stem cortex.

III-B. Chara contraria A. Br. 1. Portion of plant, natural size. 2. Portion of the stem cortex. 3. Transverse section of the stem. 4. Fertile branchlet. 5. Oospore.

III-C. Chara foetida A. Br. 1. Portion of plant, natural size. 2. Portion of stem showing size attained. 3. Portion of plant, natural size. 4. Portion of transverse section of the stem. 5. Basal portion of a branchlet. 6. Portion of a transverse section of the stem. 7. Basal portion of a branchlet.

short, stout, and blunt; lowest branchlet internode diplostichous; tip of branchlet of 1-4 ecorticate cells sometimes forming a long whip-like extremity; bracteoles from about as long as oogonia to 5 times their length; posterior bract cells usually papilliform, but sometimes length developed to 4-5 times breadth; oospores with 10-14 ridges, 0.53 to 0.74 mm. long, brown to black; antheridia up to 0.58 mm. in diameter.

Included here are specimens reported by Bessey (11) in a supplementary list, "89. *Chara foetida* A. Br. collected by J. M. Bates at Valentine, (Bessey)."; Bessey and Webber (12), "834. *Chara* sp. in ponds . . . Thedford; Belmont.": Woods (23), *"Chara foetida* A. Br. Form *subinermis longibracteata* A. Br. Pumpkinseed creek, Cheyenne county; Kimball; Ponca river, Boyd county. Form *subhispida microptila* et *brachyteles* A. Br. Buffalo Creek, Haigler. *Chara crassicaulis* Schleich. Form *subinermis macrophylla* and Form *subhispida macrophylla longibracteata* Pine Ridge (type and forms mixed), Haigler form 2."; Nebraska Bot. Surv. III (13), *"Chara crassicaulis* Schleich. Haigler (3366, 3367), Pine Ridge. (3368)."

No specimens were seen to support the following reports: Woods (23), "Form *subinermis longibracteata* A. Br., Cherry county. Form *subhispida macroptila* et *macroteles*. Cherry county.". Anderson and Walker (10), *"Chara foetida rabenhorstii";* Pound and Clements (19) reported *Chara foetida longibracteata* A. Br. from "pools and small lakes in the wet valleys of the Loup district."

The specimen reported by Smith and Pound (21) as *Chara foetida* A. Br. var. *longibracteata* (264) was changed in the Nebraska Bot. Surv. III (13) to *Chara evoluta* Allen and appears as such in this paper.

Robinson (20) cites illustration in Woods (23) Pl. 32.

Some authors have divided the group of plants within the range of the above description into numerous varieties, subspecies, or new species many of which might be recognized in the Nebraska Characeae. However, the extent of variation within this species complex and even in the same plant sometimes results in considerable confusion; so for the present the following possibilities are cited only to show the extremes that may be found:

(subsp.) *crassicaulis* A. Br.—stem stout, secondary cortical cells very prominent; posterior bract cells about twice as long as broad (sometimes shorter); oospores 0.52-0.62 mm. long; spine cells short and blunt; branchlets short, incurved. Plate IV-A, figs. 1, 4, 6.

(Specimen illustrated: Dawes county, Fort Robinson, *H. J. Webber 6533,* July 31, 1889.)

(var.) *subhispida* A. Br.—stem stout, secondary cortex very prominent, irregular; posterior bract cells usually long; bracteoles long; oospores 0.46-0.55 mm. long; spine cells long and deciduous; branchlets long. Plate III-C, figs. 1, 2, 4, 5.

(Specimen illustrated: Dundy county, Buffalo creek, Haigler, *Woods* and *Saunders, Bottle C,* Aug. 4, 1893.)

(var.) *longibracteata* A. Br.—stem stout; cortex regular; bracteoles up to six times length of fruit; spine cells short. Plate III-C, figs. 3, 6, 7, (Specimen illustated: Keith county, gravel pit pond, Kingsley Dam, *Walter Kiener 15490,* Sept. 13, 1943.)

(sp. nov.) *Chara intumescens* Robinson—(Woods' illustration of *Chara crassicaulis* forma *subhispida longibracteata* cited) stem stout; cortex regular, cells about equal; posterior bract cells papilliform to 4 times as long as broad; bracteoles usually greatly exceeding oogonia; oospores 0.56-0.63 mm. long; spine cells variable. Plate IV-A, figs. 3, 5, 7.

(Specimen illustrated: Dundy county, Haigler, *Woods* and *Saunders,* Aug. 4, 1893.)

Specimens seen: Banner county: probably *Chara foetida* A. Br. Pumpkinseed valley in creek, *Rydberg,* no date given but date on newspaper in which wrapped was Aug. 11, 1891. Cass county: Louisville, probably *Smith* and *Pound,* about 1892. Boyd county: Ponca river, *Clements,* 1893. Cherry county: probably *C. foetida,* Valentine, *John M. Bates,* June 1890; Valentine, *John Bates,* Aug. 26, 1891; probably *C. foetida,* Valentine, *Bates 58b,* Aug. 26, 1891; Wood Lake, *J. M. Bates 7280, 1146,* Aug. 13, 1898; with *C. fragilis* Desv., Watts lake, *Elda Walker 42,* July 17, 1912. Dawes county: Pine Ridge, *Webber,* June 29, 1889 (Herbarium sheet no. 2776 in the Univ. of Neb. Herb. was apparently *C. foetida* alone, but sheet no. 2774 bearing similar label had some *C. evoluta* mixed with it.); pond in canyon, Belmont, *H. J. Webber 6534 (no. 2),* July 20, 1889; Fort Robinson, *H. J. Webber 6533,* July 31, 1889; Crawford, *J. M. Bates,* June 23, 1891; Crawford, *J. M. Bates 658* and *7287,* July 13, 1897. Dundy county: Haigler, *Woods* and *Saunders Bottle C, Bottle D,* one without label, Aug. 4, 1893. Greeley county: Greeley Center, *Tom A. Williams,* date (?) (This probably is the specimen reported by H. J. Webber, 22, "150. *C. fragilis* Desv. In ponds. Greeley Center —Williams)". Keith county: gravel pit pond, Kingsley Dam, *Walter Kiener 15490,* Sept. 13, 1943. Kimball county: Kimball, *Rydberg,* 1891. Merrick county: U. P. sand pit, Central City, *Irene Mueller,* July 4, 1936. Morrill county: probably *C. foetida* A. Br., Pumpkinseed creek, *Jared G. Smith,* Aug. 23, 1889. Sioux county: Canyon creek, Hat Creek Basin, *H. J. Webber 6535,* Aug. 2, 1889. Thomas county: Thedford, *H. J. Webber 6525* (*No. 4*), July 10, 1889, *6526,* Aug. 7, year (?), *6527* (*Th. 14*), *6528* (*Th. 14*), *6529* (*Th. 14*), *6530, 6531* (*Th. 14*), *6532,* date (?).

10. CHARA FRAGILIS Desv. in Loiseleur Not. aj. Fl. France p. 137. 1810.

Plate IV-B.

Habit variable, slender; stem internodes slightly longer than branchlets; whorls of 9 branchlets; monoecious; stem regularly triplostichous, cells about equal; spine cells usually undeveloped, at times, however, papillae are formed; stipulodes in two series, usually rudimentary but occasionally developed; lowest branchlet internode diplostichous; tip of branchlet made up of 1-3 short ecorticate cells; bracteoles usually much shorter than but sometimes as long as oogonia; posterior bract cells undeveloped or papilliform; coronulae usually of long, slender, connivent cells; oospores with 10-14 ridges usually extended downward into a cage, 0.48-0.66 mm. long, dark brown to black; antheridia up to 0.42 mm. in diameter.

Included here is the specimen reported by Smith and Pound (21), "*Chara fragilis* Desv. In small lake, Cherry county, July 19. (262)".

No specimens were seen to support the following reports: Webber (22), "150. *C. fragilis* Desv. In ponds, Greenwood, Fremont. (Williams)."; Anderson and Walker (10), "Phalaris lake. *Chara fragilis*"; Pound and Clements (19), *C. fragilis* from "pools and wet valleys of the Loup district."

Robinson (20) cited illustration in Woods (23) Pl. 35.

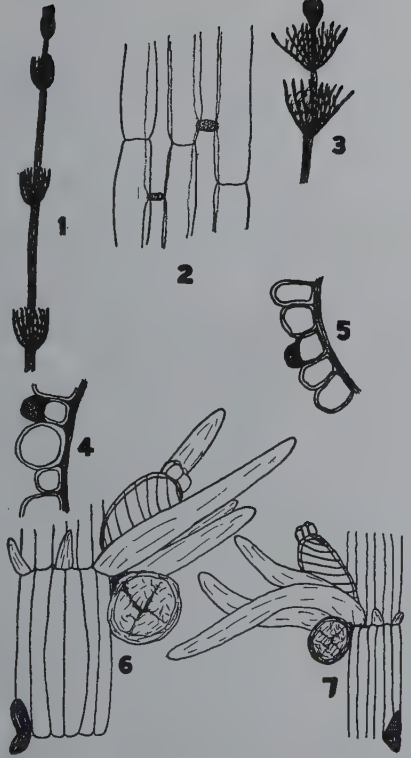
Specimens seen: Mixtures from Grant, Cherry and Dawes counties: lakes 3 mi. N. E. of Whitman, Wood Lake, and Crawford, *J. M. Bates,* date (?) (This may include the specimen which is the basis for the report by Woods (23) p. 128, "*Chara fragilis* Desv.—Whitman.": Arthur county: in intermittent sandhill pool, Arthur, 3 mi. south, *Walter Kiener 15444,* Sept. 10, 1943; offset pond, Beeken lake, *Walter Kiener 16034* and *16036,* Oct. 22, 1943; probably *C. fragilis,* offset pond, Beeken lake, *Walter Kiener 16035,* Oct. 22, 1943. Brown county: Long Pine, *J. M. Bates,* June 9, 1894. Cherry

COUNTY: probably *C. fragilis* Desv., Valentine, *Bates 58,* Aug. 26, 1891; *Smith* and *Pound 262,* July 19, 1892 (herbarium sheet in the Univ. of Neb. Herb. no. 2770 was apparently *C. fragilis* alone, but sheet no. 2771 bearing a similar label had some *C. coronata* mixed with it); Wood Lake, *J. M. Bates 1145,* Aug. 13, 1898 (herbarium sheet no. 25775 in the Univ. of Neb. Herb. was apparently *C. fragilis* alone, but no. 23196 bearing a similar label had a mixture with *C. verrucosa*); with *C. foetida* A. Br., Wood Lake, *J. M. Bates 1146,* Aug. 13, 1898; with *C. contraria* A. Br., Watts lake, *J. M. Bates,* July 10, 1894; Watts lake, *Elda Walker 42,* July 17, 1912; Hackberry lake, *E. Palmatier* and *T. R. Porter,* June 11, 1936; lake bottom 3 ft. deep, Hackberry lake, *E. Palmatier* and *T. R. Porter,* Kiener Herb. no. *13779,* June 13, 1936. HALL COUNTY: gravel pit pond, near Grand Island, *Walter Kiener 15159,* Aug. 28, 1943. HAMILTON COUNTY: submerged in sandpit lake, Platte river near Phillips, *Walter Kiener 14852* (two portions mounted separately—one dried from formalin, the other dried from the natural state), *14857,* July 30, 1943; with *C. contraria* A. Br. submerged in sandpit lake, Platte river near Phillips, *Walter Kiener 14855,* July 30, 1943. HOLT COUNTY: Chambers, *George Herzog,* 1929. KEITH COUNTY: gravel pit pond, Kingsley Dam, *Walter Kiener 15494,* Sept. 13, 1943; dried up pool, west of Keystone, *Walter Kiener 15704,* Sept. 24, 1943; sandhill pond, Kingsley Dam, 9 mi. north, *Walter Kiener 16080, 16081, 16088,* Oct. 27, 1943; probably *C. fragilis* Desv., sandhill pond, Kingsley Dam, 9 mi. north, *Walter Kiener 16082,* Oct. 27, 1943. THOMAS COUNTY: Dismal river, *H. J. Webber 6523* (*No. 6*), July 13, 1889. WEBSTER COUNTY: Red Cloud, *John M. Bates,* July, 1905.

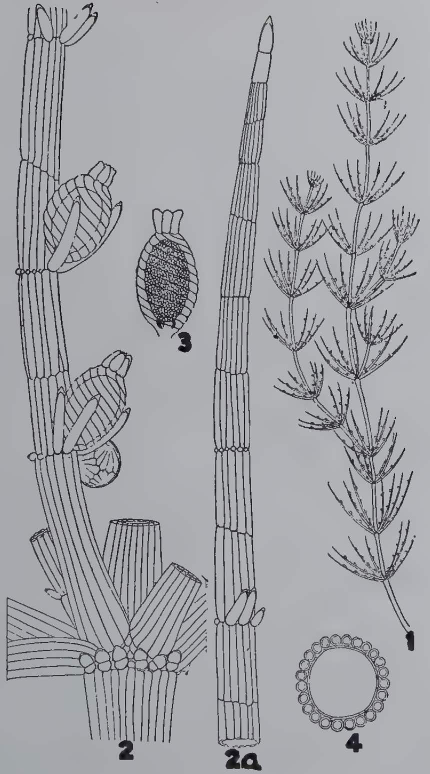
11. CHARA VERRUCOSA Itzig. Bot. Zeit. 8: 338. 1850.

Plate IV-C.

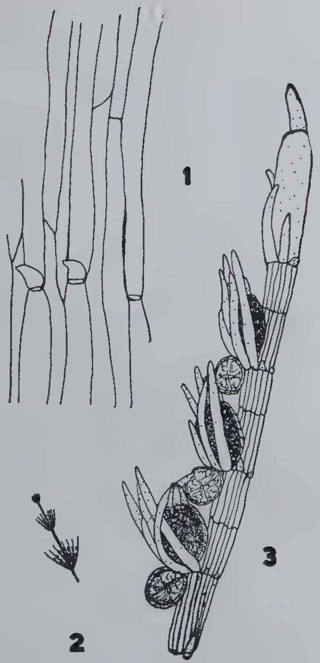
Habit similar to *Chara fragilis* Desv. but smaller and more rigid; about 7 branchlets in a whorl; monoecious; stem triplostichous with the primary cells larger and more prominent than the secondary, secondary cells sometimes irregular; spine cells papilliform up to short cells about 0.08 to 0.13 mm. long, pointed, stipulodes in two series, upper 0.21 mm. long, lower about 0.08 mm.; lowest internode of branchlet diplostichous; tip of branchlet of 1-3 ecorticate cells; bracteoles a little longer than oogonia; posterior bract cells papilliform; no mature oogonia or antheridia seen but according to Robinson (20),



IV-A



IV-B



IV-C

IV-A. Chara foetida A. Br. 1. Portion of plant, natural size. 2. Portion of stem cortex. 3. Portion of plant, natural size. 4. Portion of transverse section of stem. 5. Portion of transverse section of stem. 6. Basal portion of branchlet. 7. Basal portion of a branchlet.

IV-B. Chara fragilis Desv. (Rearranged and reproduced from Woods, 23, Pl. XXXV.) 1. Portion of plant, one-half natural size. 2. The base of a verticel with one branchlet showing a few basal internodes. 2a. The remainder of the branchlet shown in fig. 1. 3. Oogonium containing oospore. 4. Portion of a transverse section of a stem.

"oospores 0.63-0.8 mm. long, 0.47-0.6 mm. wide with 11-13 striae; antheridia 0.35-0.56 mm. in diameter."

Specimens seen: Cherry county: with *Chara fragilis* Desv. in Wood Lake, *J. M. Bates 1145,* Aug. 13, 1898; "Phalaris" lake, *Elda R. Walker 37,* July 15, 1912.

12. CHARA ASPERA Willd. Ges. Naturf. Fr. Berlin Mag. 3: 298. 1809.

Plate V-A.

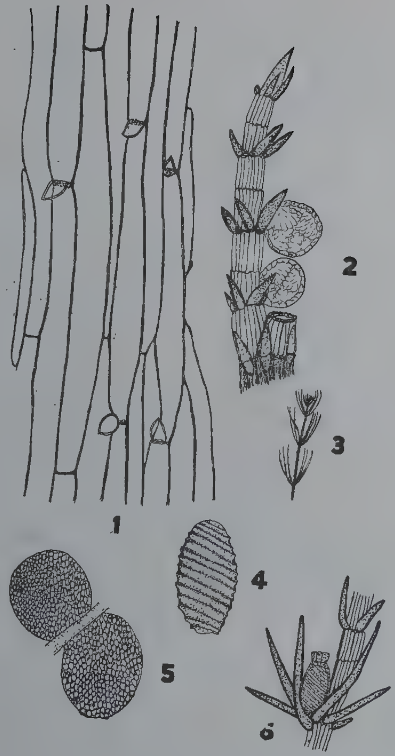
Habit small, about 4 cm. high, resembling *Chara fragilis* Desv.; slightly incrusted; almost spherical bulblets; about 7 branchlets at node with 5 segments each; dioecious; stem unevenly triplostichous appearing diplostichous at times, sometimes secondary cell ends overlap a considerable distance, other irregularities also occur such as secondary cells developed in only one direction from node or developed only a short distance in both directions, size of cells variable also; spine cells papilliform to 0.2 mm. long, sharply pointed; 2 series of well developed stipulodes, upper row about 0.32 mm. at a mature node, lower about 0.16 mm., both quite variable from node to node and at the same node; branchlet diplostichous, tip of branchlet made up of 1-2 short uncorticated cells; bracteoles apparently considerably longer on female plant than on male plant, 0.7-1.0 mm. long, 0.08-0.12 mm. wide on female, 0.43 mm. long and about 0.08 wide on male, variable; posterior bract cells also apparently larger on female than on male, 0.16 mm. long and 0.05-0.08 mm. wide on male, 0.27-0.56 mm. long and about 0.08 mm. wide on female; oospores with 13 ridges, 0.43-0.45 mm. long and about 0.27 mm. wide., black; antheridia about 0.53 mm. in diameter; only immature ones seen.

Specimen seen: Cherry county: Big Alkali lake, *Elda R. Walker 36,* July 15, 1912.

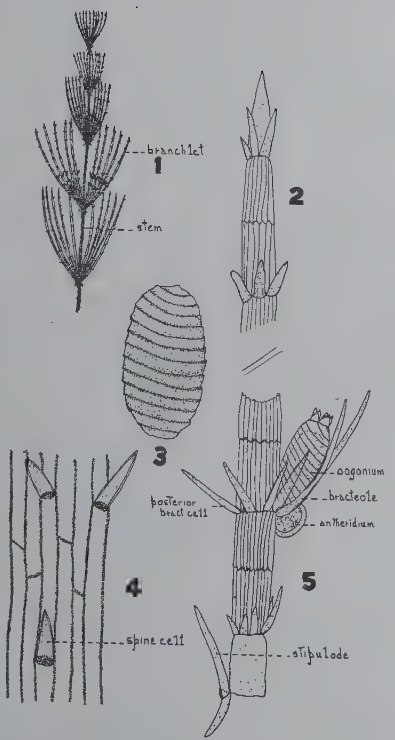
13. CHARA GYMNOPUS A. Br. Uebersicht der Schweizerischen Characeen, Neue Denkschr. d. allgemeinen Schweiz. Ges. f. d. gesammten Naturw. 10: 13. 1849. char. emend.

Plate V-B.

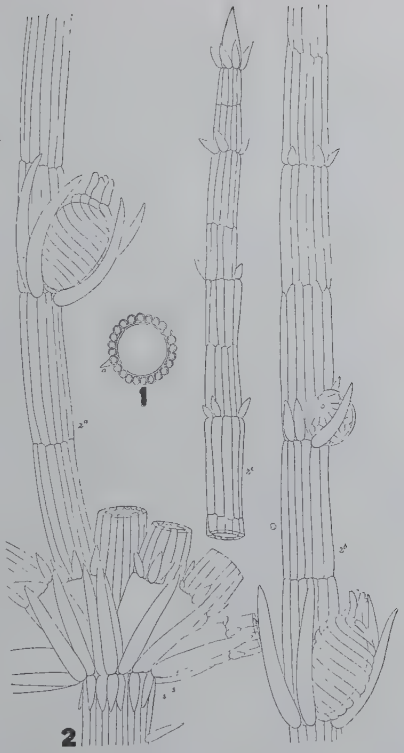
Habit usually lax and flexible; upper stem internodes shorter than branchlets; lower whorls remote, about 10 branchlets in a whorl, having 9-10 segments; monoecious; rather regularly triplostichous, cells about equal; spine cells borne singly, long; stipulodes in two



V-A



V-B



V-C

V-A. CHARA ASPERA Willd. 1. Portion of stem cortex. 2. Fertile branchlet of male plant showing portion of stipular whorl. 3. Portion of female plant, natural size. 4. Oospore. 5. Bulblets. 6. Portion of branchlet from female plant.

V-B. CHARA GYMNOPUS A. Br. 1. Portion of plant, natural size. 2. Tip of branchlet. 3. Oospore. 4. Portion of stem cortex. 5. Basal portion of branchlet.

V-C. CHARA SEJUNCTA A. Br. (Rearranged and reproduced from Woods, 23, Pl. XXXVI.) 1. Transverse section of the stem.

series, long, slender, sharply pointed, variable in length, upper series about 0.64-0.85 mm. long, lower about 0.32 mm. long; lowest branchlet internode uncorticated, variable in length but about as long as broad—covered by upper row of stipulodes; next lowest internode triplostichous; first branchlet node may be fertile; tip of branchlet bears one uncorticated short cell; bracteoles about as long as fruit; posterior bract cells about one-half as long as fruit at fertile node; short bracts produced all around branchlet at sterile nodes; bracteoles and bract cells at first branchlet node similar to rest; oospores with 13 or 14 ridges, about 0.61 mm. long, black; membrane dark brown, with granules; antheridia on specimen studied probably immature, 0.27 mm. in diameter.

Some authors divide this species into subspecies, but confusing intermediates occur, so none are mentioned at this time.

Specimen seen: DODGE COUNTY: submerged in sandpit lakes at Fremont, *Walter Kiener 14795,* July 23, 1943.

14. CHARA SEJUNCTA A. Br. in pl. Lindh. (Boston Journ. of Nat Hist. 5: 263. 1845.) p. 56. Monatsber. d. Bul. Akad. 1858.

Plate V-C.

Habit similar to *Chara gymnopus* A. Br.; 8-10 branchlets with about 10 segments each; monoecious, but antheridia and oogonia borne on different branchlet nodes; the stem regularly triplostichous, the cells about equal in diameter; spine cells short and sharply pointed; two series of well developed stipulodes, the upper row about 0.8 mm. long, the lower about 0.2 mm. long; the upper row of stipulodes almost conceals the uncorticated lowest branchlet internodes; next to the lowest branchlet internode triplostichous; one short uncorticated cell surrounded by several sharply-pointed bract-cells is found at the tip of the branchlet; bracteoles about as long as oogonia; posterior bract cells papilliform. In the portion of the specimen studied, no mature antheridia or oogonia were found, but according to Woods (23) oospores are 0.63 x 0.36 mm.; antheridia 0.36-0.38 mm. in diameter.

Robinson (20) cited illustration in Woods (23) Pl. 36.

Specimen seen: KEARNEY COUNTY: Minden, *H. Hapeman,* Sept. 7, 1891 (probably the basis of the reports by the Nebraska Bot. Surv. III (13), "*Chara sejuncta* A. Br. Minden. (3365)"; Woods, 23, "*Chara sejuncta* A. Br. Minden".).

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